U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF SOILS—MILTON WHITNEY, Chief.

IN COOPERATION WITH THE UNIVERSITY OF CALIFORNIA AGRICULTURAL EXPERIMENT STATION, THOMAS F. HUNT, DIRECTOR; CHARLES F. SHAW, IN CHARGE SOIL SURVEY.

# SOIL SURVEY OF THE EL CENTRO AREA, CALIFORNIA.

BY

.. T. STRAHORN, In Charge, E. B. WATSON, A. E. KOCHER, and E. C. ECKMANN, of the U. S. Department of Agriculture, and J. B. HAMMON, of the University of California.

MACY H LAPHAM, Inspector, Western Division.

[Advance Sheets—Field Operations of the Bureau of Soils, 1918.]

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## LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Soils,
*Washington, D. C., June 25, 1921.*

Sir: In the extension of the soil survey in the State of California during the field season of 1918 a survey was undertaken in the El Centro area. This work was done in cooperation with the University of California Agricultural Experiment Station.

I have the honor to transmit herewith the manuscript report and map covering this work and to request their publication as advance sheets of Field Operations of the Bureau of Soils for 1918, as authorized by law.

Respectfully,

Milton Whitney,
*Chief of Bureau.*

Hon. H. C. Wallace,
*Secretary of Agriculture.*

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# SOIL SURVEY OF THE EL CENTRO AREA, CALIFORNIA.

By A. T. STRAHORN, In Charge, E. B. WATSON, A. E. KOCHER, and E. C. ECKMANN, of the U. S. Department of Agriculture, and J. B. HAMMON, of the University of California.—Area Inspected by MACY H. LAPHAM.

## DESCRIPTION OF THE AREA.

The extreme southern portion of California, the northern limits of which are quite definitely marked by ranges of hills and mountains extending from the Pacific Ocean, just north of Santa Monica, eastward to the Colorado River, is divided by the Peninsula Range of mountains into what are known as the coast and desert regions. This range begins at Mount San Jacinto and extends southerly into the Mexican territory of Lower California. Its eastern front is a steep rugged escarpment; west of its crest the mountainous region is a complicated system of small mountain valleys and ridges, the drainage of which is into the Pacific Ocean.

Fig. 1.—Sketch map showing location of the El Centro area, California.

The desert region, which is known as the Colorado Desert, includes an area between the Peninsula Range on the west; the Cottonwood, Chocolate, and Chucawalla Mountains and the Colorado River on the north and east; and a line in Lower California on the south. The area of this desert is about 8,000 square miles, the larger part lying within the United States. Approximately 2,200 square miles of it lie below sea level and was formerly known as Salton Sink,[1] consisting of a depression surrounded by a nearly continuous beach line, now slightly above present sea level, which marks the extent of a former extensive body of water that occupied this part of the desert.

The old beach line plainly divides the desert into two physiographic divisions, the lower including the Imperial Valley and Salton

[1] The term "Salton Sink" was originally applied to all of the depression included within the old beach line, but since the occupation and devolpment of the desert by man, the term usually has been applied to the lowest part, at present occupied by a body of water known as the Salton Sea. The term "Imperial Valley" refers to the adjacent areas, now largely under irrigation.

Sink and the upper, all of the extensive and irregular desert areas lying between the old beach line and the outer limits of the Colorado Desert region. The first is a uniform plain, sloping gently to the north, the surface of which is broken only by the channels of New and Alamo Rivers, and by occasional bodies of Dunesand. Its elevation ranges from about 35 feet above sea level, along the old beach line, to 287 feet below sea level at the lowest point. The areas above the beach line consist, for the larger part, of uniform to moderately rolling plains rising gradually to the several boundaries. Shallow intermittent stream ways have given rise to local irregularities, and occasional partly buried mountain masses and extensive sand dunes form the only conspicuous elevations above the general level of the surface. This part of the desert has its lowest elevation along the old beach line about 35 feet above sea level and its highest about 500 feet above sea level, at the bases of the bordering mountains, and in the isolated prominences on the floor of the desert, which range from 500 to over 2,000 feet above sea level.

The El Centro area is located in Imperial County in the extreme southern part of the Colorado Desert, the southern boundary of the area being the international boundary line between the United States and Mexico. The northern, eastern, and western boundaries of the area are formed by certain section and township lines of the recent resurvey of this region by the United States Land Office. The eastern boundary line of the area is about 35 miles west of the California-Arizona State line. The area surveyed has an extent of 540 square miles, or 322,560 acres.

Prior to 1905 and 1906 the only evident irregularities in topography of the surface were the shallow depressions serving as the channels of New and Alamo Rivers, a low escarpment around what was known as Mesquite Lake, and a number of large bodies of Dunesand. Extensive areas of land were literally as smooth as a floor, but over much of the area the surface was dotted with small mounds of wind-blown material lodged on the windward side of clumps of desert vegetation.

During a period of several months in 1905 and 1906 the Colorado River, instead of following its usual course to the Gulf of California in Mexico, turned its flood into this basin and occupied the channels of the New and Alamo Rivers. During the early periods of the flood from the Colorado River these old channels were entirely inadequate, and the waters spread out over extensive adjacent areas. The slope of the valley was sufficient to give the water considerable velocity, and the erosion of the former channels of the streams, beginning at a point near the Sink, progressed rapidly southward to some distance south of the international boundary line. This

erosion was most severe along the channel of New River, the results being a sinuous gorge some 30 miles long and 50 to 100 feet or more deep with numerous tributary channels, some of which were but little smaller than the main gorge. The banks of these channels for the greater part of their length are vertical from the top nearly to the bottom. (Pl. I, Fig. 1.)

The immediate flood plain of New River is but little above the normal water surface of that stream and is subject to recurring overflows when unusually large volumes of waste irrigation water are turned into the stream. The area of this flood plain forms but a small part of the bottom of the gorge, the larger part being eroded and lying several feet above the flood plain.

The former channel of the Alamo River has suffered less from the effects of the flood than that of New River. In places it is hardly 50 feet wide and less than 20 feet deep; in other places it may be more than half a mile in width and have a depth of 100 feet or more.[2] The immediate channel of this stream has developed no flood plain, but is depressed several feet below the adjacent lowlands. These latter may be either rolling eroded lands or occur as fairly uniform or rolling terraces, of which as many as three exist in several localities.

Mesquite Lake, which lies several miles east of the town of Imperial, is a shallow flat-bottomed depression bordered by a low eroded escarpment. Prior to the time of the flood, this occasionally carried overflow waters from the Alamo River. At the time of the flood, a new connection was made with the Alamo at a lower point, so as to assist in the removal of the flood waters, and the former inlet was closed.

On the eastern side of the valley, the sea-level contour enters the area near the northeastern corner, passes southward about 4 miles east of Holtville, thence a few miles in a southerly direction and, swinging sharply northward, returns to a point about a mile south of the town of Holtville. Its course is then southwesterly, passing across the international boundary line at the junction of the latter and the channel of New River. On the western side of the valley, this contour parallels the old beach line very closely, lying about one-half mile east of it. Most of the towns within the area lie below sea level, El Centro having an elevation of about 50 feet; Imperial, about 67 feet; Heber, 17 feet; Holtville, 10 feet; and Seeley, 25 feet below sea level. Calexico is about 5 feet above sea level.

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[2] "In the period, about nine months, when the flood waters of the Colorado River were flowing down to Salton Sink, the waters carried away a yardage of earth almost four times that excavated from the Panama Canal. The combined length of the channels cut out was almost 43 miles, the average width being 1,000 feet, and the depth 50 feet. To this total of from 400,000,000 to 500,000,000 yards of earth must be added almost 10 per cent more for side canyons, surface land erosion, etc." (Transactions, American Society of Civil Engineers, Professional Paper No. 1270, p. 1324, H. T. Corey.)

On the western side of the valley, the old beach line has an elevation of about 35 feet above sea level. West of that line, there is a gradual increase in elevation, the southwestern corner of the area lying about 150 feet above sea level. On the eastern side of the valley the elevation of the beach line is about 50 feet above sea level and the limited area of desert land lying between that line and the eastern boundary of the area is slightly both above and below that elevation.

The higher desert parts of the area on the western side of the valley have a marked fall toward the axis of the valley, and the drainage of this region is effected by numerous characteristic desert drainage ways. These are wide, shallow, sandy bottomed water courses, often having poorly defined banks. These channels are dry year after year, and carry water for a brief interval only after long and heavy storms in the higher mountains or adjacent desert regions. None of the water reaches any large streams, all of it being absorbed by the sands within a short distance below the old beach line. On the eastern desert the surface relief is too low and flat to form any system of surface drainage.

Within the present irrigated area there are few surface drainage channels. The slope of the land to the north would be sufficient to develop drainage courses in a region of heavier precipitation, but the small and very infrequent rainfall of this region is not sufficient to form even local arroyos or gullies. The channels of New and Alamo Rivers afford a means of removing waste irrigation waters from canals and from adjacent lands, and wasteways have been constructed to those streams for the purpose of regulating the flow of water in the canals.

Spanish explorers and padres from the early missions in what is now Arizona and New Mexico and in the northern part of Mexico carried on extensive explorations throughout the Southwest early in the sixteenth century, and two parties explored the lower Colorado River as early as 1540. What is now known as the Salton Sink and the Imperial Valley were probably seen during that year, and following the founding of the several missions in southern California early in the eighteenth century it is probable that there was more or less travel between them and the missions east of the Colorado River.

A number of explorations were made by Americans at various times after 1825, the most notable being that of the Williamson party in 1853. That party had for its object the discovery of a pass across the western mountains for a railroad route to the Pacific coast, and during the exploration they crossed the northern portion of this desert. In 1851 Butterfield established a stage route across the desert from Yuma to the coast, the route crossing the southern portion of the El Centro area. This route was in continual opera-

tion until in 1879, when the Southern Pacific Railroad was constructed from Yuma to Los Angeles.

Prior to the construction of the present irrigation system the population of the desert was confined to the few people at each of the railroad stations along the line of the railroad and the few Indians on the Yuma Indian Reservation along the Colorado River. Facilities for irrigation soon attracted large numbers of farmers to the area. The desert may be said to have had no permanent population in 1900; in 1910, according to the Federal census, Imperial County had a population of 13,591, the larger part of whom resided in the Imperial Valley. In 1910 the population of the El Centro area was about 8,800 and in 1917 it was estimated (school census) to be about 28,000. The population of Imperial County in 1920 had reached 43,453. Before the development of the present irrigation system this district was included in San Diego County, but in 1907 the eastern part of that county was separated to form Imperial County, with El Centro as the county seat.

El Centro, established in 1906, had a population of 1,610 in 1910. According to the 1920 census the population is 5,464. This place lies about 30 miles south of the main line of the Southern Pacific Railroad, on the Imperial Valley branch of that line, and is the present eastern terminus of the San Diego & Arizona Railroad, a line recently completed between El Centro and San Diego. A local railroad, the Holton Interurban, extends eastward from El Centro for about 11 miles to the town of Holtville.

Calexico, 9 miles southeast of El Centro, is located on the Mexican border, just within the United States. Its population, which in 1910 numbered 797, in 1920 had increased to 6,223. It is at the southern terminus of the Imperial Valley branch of the Southern Pacific, and a continuation of that line, known as the Inter-California Railway, extends southeasterly through Mexican territory, and meets the main line of the Southern Pacific at Yuma, Ariz.

Imperial, which was the first town to be established in the valley, is 4 miles north of El Centro. Its population in 1910 was 1,257, and in 1920, 1,825. The population of Holtville, situated 11 miles east of El Centro, was 727 in 1910 and 1,347 in 1920. Seeley, 9 miles west of El Centro, Dixieland, on the edge of the desert, just west of the Main West Side Canal, and about 13 miles west of El Centro, and Heber, 6 miles southeast of El Centro, are smaller towns in the area.

The main line of the Southern Pacific Railroad, between Los Angeles and New Orleans, passes across the northern part of the desert, about 25 miles north of the northern boundary of the El Centro area, and a branch of that line, known as the Imperial Valley branch, passes southwesterly through the central portion of this area.

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One link of the State highway system, a concrete highway 20 feet in width, extends westward from El Centro beyond the limits of the area. Except in the more thinly settled portions of the area, or where there are considerable areas of wind-blown sand, good dirt roads occur on nearly every section line, and in some localities are only a half mile apart. All the main roads are about twice as wide as the usual country road, and are divided into two parts by a low ridge, or levee, extending down the center. As the rains in this region are not sufficient to keep down the dust and maintain the surface of the road in a favorable condition for travel, the practice is to flood the road, at intervals, on one side of the levee and restrict travel to the other side. When the flooded side has become dry and is in the proper condition traffic is diverted to it and the opposite side is then covered with water. In addition to the regular roads there are narrow roads along the tops or at the base of the canal banks, which are largely used by ditch riders in the performance of their duties.

The outside markets for the products of the area cover the entire country. Lettuce, peas, asparagus, and muskmelons go to all the larger cities. The cotton is sent to the manufacturing towns of the East. Stock and dairy products are shipped largely to the several markets on the Pacific Coast.

## CLIMATE.

The climate of the Imperial Valley is decidedly arid. Its chief characteristics are exceptionally hot summers, with relatively high temperatures throughout the entire year; a low annual rainfall; a rapid rate of evaporation; and a large percentage of sunshiny days. The summers are long and hot, temperatures of 100° F. or more being recorded for Calexico for every month from March to October, inclusive. During the months of May, June, July, and August temperatures have risen to 117° F. at that station, yet so low is the relative humidity that this degree of heat is no more oppressive than 100° F. in humid regions. The winters are short and mild. Temperatures slightly lower than 32° F. may be expected occasionally from December to February, inclusive. Killing frost has occurred at Calexico as late in the spring as March 25 and as early in the fall as November 13. The average date of the last killing frost in the spring is reported as February 5, and that of the earliest in the fall as December 4. This gives an average growing season of 302 days, while alfalfa, many vegetables, and even strawberries thrive throughout the winter.

The rainfall is very light, the minimum for any year so far of record being 0.64 of an inch. The average at Calexico is reported as 3.12 inches. Rain usually comes in severe storms at long intervals,

the irregularity of which makes rainfall entirely unreliable, even as a supplement to irrigation.

The following table gives the normal monthly, annual, and seasonal temperatures and precipitation at Calexico, Calif.:

*Normal monthly seasonal, and annual temperature and precipitation at Calexico.*

| Month. | Temperature. | | | Precipitation. | | |
|---|---|---|---|---|---|---|
| | Mean. | Absolute maximum. | Absolute minimum. | Mean. | Total amount for the driest year. | Total amount for the wettest year |
| | °F. | °F. | °F. | Inches. | Inches. | Inches. |
| December | 52.5 | 82 | 25 | 0.04 | 0.00 | 0.54 |
| January | 53.7 | 78 | 21 | .28 | T. | 1.50 |
| February | 57.8 | 88 | 29 | .80 | .00 | 3.76 |
| Winter | 54.7 | 88 | 21 | 1.12 | T. | 5.80 |
| March | 63.6 | 100 | 32 | .27 | .04 | .91 |
| April | 70.0 | 104 | 41 | .25 | .00 | .50 |
| May | 74.9 | 116 | 41 | .09 | .00 | .00 |
| Spring | 69.5 | 116 | 32 | .61 | .04 | 1.41 |
| June | 83.4 | 116 | 54 | .03 | .00 | .00 |
| July | 89.5 | 117 | 62 | .07 | .08 | .03 |
| August | 89.6 | 117 | 56 | .70 | T. | .00 |
| Summer | 87.5 | 117 | 54 | .80 | .08 | .03 |
| September | 83.5 | 110 | 50 | .09 | .52 | .13 |
| October | 72.3 | 105 | 42 | .16 | .00 | .00 |
| November | 61.9 | 99 | 28 | .34 | T. | 1.96 |
| Fall | 72.6 | 110 | 28 | .59 | .52 | 2.09 |
| Year | 71.6 | 117 | 21 | 3.12 | .64 | 9.33 |

Strong winds are of frequent occurrence during the spring and occasional dust storms are experienced throughout the year. Aside from the drifting of the lighter textured soils and the unpleasantness of carrying on field work or other farming operations during these storms, the winds have little influence on agriculture. The periods of high winds are of short duration. These storms are about the only feature to mar what would otherwise be an almost perfect winter climate.

Owing to the extreme dryness of the atmosphere and the intense sunshine during the greater part of the year, the rate of evaporation is very high. The following table, compiled from measurements made by the California Development Co., shows the average annual loss from a water surface at Calexico, Calif., for a 3-year period to be 80.66 inches, or 6.72 feet.

*Evaporation from a water surface at Calexico, Cal.*

| Month. | 1904 | 1905 | 1906 | Average for three years. |
|---|---|---|---|---|
| | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| January | 4.39 | 2.72 | 2.57 | 3.23 |
| February | 6.32 | 1.47 | 2.43 | 3.40 |
| March | 8.36 | 4.14 | 5.06 | 5.91 |
| April | 9.55 | 4.74 | 5.99 | 6.76 |
| May | 10.91 | 8.38 | 6.84 | 8.71 |
| June | 13.89 | 12.86 | 7.41 | 11.39 |
| July | 12.47 | 10.43 | 6.76 | 9.89 |
| August | 10.98 | 8.52 | 8.47 | 9.32 |
| September | 8.61 | 7.83 | 6.73 | 7.72 |
| October | 8.78 | 6.77 | 5.45 | 7.00 |
| November | 5.40 | 3.23 | 3.61 | 4.08 |
| December | 3.48 | 3.43 | 2.40 | 3.10 |
| Annual | 103.61 | 75.00 | 63.66 | 80.66 |

## AGRICULTURE.

The beginning of agriculture in the El Centro area was different from that of most regions in that it had a very definite beginning. There was absolutely no agriculture in the area prior to 1900. It was a desert with no possibility of crop growing or stock raising, because there was no water available for irrigation; but with the opening of the ditches, described elsewhere, agriculture developed very rapidly. Settlers began to come into the Imperial Valley in 1900, but probably not more than a score of people spent the summer, or any considerable part of it, in the valley, and these were mostly workers employed in the preliminary details of organization. In the fall of 1900 a large number of persons took up land, but the work preliminary to planting of this land was not done to any extent until late in the spring of 1901, for the reason that it was impossible before that time to say just when water would be available. About June of that year a small stream of water was brought to a temporary head ditch near the Mexican boundary line, and with this water several fields of sorghum, milo maize, wheat, and barley were irrigated that summer, and experimental patches of muskmelons and cotton were grown.

In the fall of 1901, after the heat of the summer was past, many more settlers came into the area, and by the 1st of December some 78,000 acres of land had been filed on. Of this land probably 8,000 acres were being prepared for cultivation. The water then available was sufficient to irrigate several hundred acres.

In April, 1903, the total acreage of crops in the Imperial Valley was about 25,000 acres, nearly all of which was within the area of

the present survey. Of this acreage, 6,220 was in wheat; 14,423 in barley; 750 in oats; 573 in alfalfa; 1,540 in preparation for corn, and the rest in grapes and other fruits, garden crops, and melons. The area planted at this time would have been much larger had the irrigation system been adequate to the demands put upon it.

By the fall of 1903 the system had been enlarged and water was turned into many new ditches, and in the winter of 1903 not less than 100,000 acres were cropped. In the fall of 1904 the settlers numbered 9,000, and in the ensuing season the crops covered nearly 150,000 acres. The products shipped from the valley in 1909, four years later, included barley, hogs, sheep, cattle, dairy products, honey, wool, asparagus, horses, hay, cotton, wheat, cantaloupes, alfalfa, meal, grapes, eggs, and poultry (including more than 1,000 turkeys), corn, and small quantities of other produce.

The leading crops of the El Centro area to-day are alfalfa, cotton, milo maize, and barley. It is impossible to give accurate acreages for these crops, for the area under consideration is only a part of Imperial County, and census statistics are available only for the county as a whole, and for the reason that crops, especially cotton, grown south of the Mexican boundary line are marketed on this side of the line and in many cases are included in commercial statistics of the valley.

Often two crops a year are grown on the same land, as, for instance, barley followed by milo or sorghum, and therefore the total acreage in crops, if it could be accurately obtained, would be somewhat greater than the total acreage of land under cultivation. The following estimates, based on personal observations and on statistics gathered by local authorities are, however, given as indicating as nearly as possible the present status of agriculture in the area. Alfalfa occupies about 30 per cent of the tilled land. The long growing season, the existence of suitable soils, and the ample supply of water give nearly ideal conditions for this crop. From five to seven cuttings are made annually, seasonal yield varying from $2\frac{1}{2}$ to 10 tons per acre, $4\frac{1}{2}$ tons being a fair average for the whole valley.[3] A much larger average yield could certainly be obtained with better farming methods. Alfalfa is used both as pasture and hay for dairy cattle, and to a small extent as feed for other cattle, horses, sheep, and hogs. A considerable proportion, probably 25 per cent, is baled and shipped from the valley. During the winter months the alfalfa is not cut but cattle are pastured on it. (Pl. I, Fig. 2.) It is a common practice to sow barley in seeding alfalfa, as this mixture gives a greater yield of hay for the first cutting.

[3] Irrigation of Alfalfa in the Imperial Valley, W. E. Packard. Bulletin 284, California Experiment Station.

A few acres of Egyptian cotton were planted among the very first crops grown in the valley. It did well, but cotton was not grown commercially until 1910. Pima cotton, a variety or strain of Egyptian cotton, was later introduced. This variety was bred in Arizona by the United States Department of Agriculture.

Cotton now ranks close to alfalfa in importance, the acreage probably approximating 35,000 acres. (Pl. II, Fig. 1.) It is estimated that half of this is occupied by short-staple varieties, 12,000 acres by Durango, and about 6,000 by Pima.

Land is prepared for cotton by plowing during the winter months when the soil is in a dry condition. Some of the cotton is planted on the level surface but most of it on ridges, 8½ feet from middle to middle. Planting begins with the Pima in February, and continues through March, April, and into early May. The land is first irrigated, by running the water down the furrows, and the cotton later planted on the top of the ridges. Best results are had where the cotton is irrigated frequently during the growing season, so as to maintain uniform moisture conditions, and where frequent cultivation is given.

The picking season extends from the last of September to the time of preparing the ground for the next crop. A large proportion of the cotton is unpicked by the first of the year, but because of the light rainfall the lint is not seriously damaged by standing in the field. In many cases a second crop is obtained from the same plants. The stalks are cut and disposed of during the winter, and the plants which have not been damaged by the winter renew their growth and produce a crop the second year. This volunteer crop is of poorer quality than the first crop, although if a good stand is obtained, the yield is satisfactory.

The price received for the cotton crop of 1917 was high, on account of war conditions. It averaged about 25 cents a pound for the short staple, 35 cents for the Durango, and 75 cents for the Pima. The price for cotton seed was from $50 to $60 a ton. The crop averaged about one-half bale per acre. The factor which has limited the yield for the last two years has been the shortage of water during the latter part of the season, which prevents proper maturing of the bolls.

The immature bolls are picked and sold separately as a low-grade cotton.

The estimated duty of water for cotton is reported by Water Co. No. 1 as 2.5 acre-feet, but it is said as much as 7 feet is sometimes used.

Bermuda grass is a great pest in the cotton fields. It is brought in by the water, as the banks of the ditches are in many places covered with this grass.

The cotton is sold through local associations or to buyers who visit the area. Most of it goes to New Orleans wholesale houses. A number of large gins are located in the towns of the area, and the seed is sent to the oil mills at El Centro and Calexico. Cotton growing the past season has been very profitable, owing to the ruling high prices, and an increased acreage is being planted in 1918. It is probable that when normal conditions return and prices fall other lines of agriculture will be found more profitable in the valley and that cotton growing will give way to a certain extent to other crops.

Nearly 25 per cent of the tilled land is in milo. This crop is sown from May 15 to September 1 and ripens in 90 to 100 days. Often two crops a year are grown. The average yield of grain is about three-fourths ton. One ton is considered a good yield, but as much as 2½ tons have been obtained. The crop, both thrashed and unthrashed, is fed to hogs and other stock. The grain is shipped out of the valley in large amounts.

Barley is the fourth crop in importance, about 20 per cent of the cultivated area being given to it. It is sown in the early winter and harvested in April. The average yield is 14 sacks per acre, with a range from 10 to 25 sacks. Most of the barley is shipped from the area. A crop of barley is often followed by a crop of milo the same year.

The main factor which has brought about the development of truck growing in the area is the extreme earliness of the season, which makes it possible to place the products on the markets of the country well ahead of the products from any other large truck-producing region in the United States. For instance, the first lettuce is shipped during Christmas week and the bulk of the crop is marketed by March. Truck crops probably occupy from 5 to 8 per cent of the tilled land of the El Centro area. This is not a large acreage compared with the leading crops, but the fact that these are intensive crops and large yields and large returns per acre are obtained gives these crops an importance much greater than their acreage would indicate. The crops, in the order of their importance, are as follows: Muskmelons, lettuce, peas, strawberries, asparagus, tomatoes, onions, and beans. California produces more muskmelons than any other State in the Union, and about one-third of the California product is grown in this area. The truck crops are shipped by express and in carload lots to all the main markets of the United States. Japanese grow most of these crops.

Table grapes, dates, and apricots do well in the area and are grown in a small way commercially. There are a few small groves of grapefruit and oranges, but plantings of any fruit are apparently not being made to any extent.

Sudan grass is a promising new crop. It is an annual and can be grown in a 50-day period after other crops have been taken off the ground. Sorgo (saccharine sorghum) is also a new crop that is receiving attention. Large yields have been obtained in experimental fields and a large acreage will be planted during the coming season. It is best utilized as ensilage for dairy cattle.

Wheat and oats are being advised by the farm centers to take the place of barley, and they are increasing rapidly in acreage.

Dairying is one of the more important industries in the area. Green feed is obtainable all the year round, and costly buildings are not needed. Some of the dairymen provide barns, others only open shelters. Shade should always be furnished. Alfalfa is the main feed, but it is supplemented with barley, milo, and pasturage in the cotton fields. All the leading breeds of dairy cattle are found in the valley, and in many cases the herds comprise excellent stock. Holstein cattle are the most numerous. There are creameries at El Centro, Heber, Holtville, Calexico, and Imperial. These handle most of the milk; very little butter is made in private dairies. At the present time (1918) many are going out of the dairy business, owing to the high price of labor and feed and the relatively low price of butter fat.

Cattle and sheep are shipped into the valley from other parts of the State and from other States, mainly during the winter months, to be fattened for the market. The numbers of beef cattle and sheep are increasing each year. Imperial County is said to lead the State in the production of hogs. Many carloads of hogs, from seven to eight months old, are sent out of the valley to the farms of the Middle West, there to be fattened on corn before reaching the final market. The mild weather during the farrowing season and the abundance of green feed make it possible to raise stock hogs very cheaply.

Large quantities of poultry, especially turkeys, are raised in the area. Holtville is the center of this industry. In October and November, 1917, more than $40,000 worth of turkeys were shipped from that station. During a single week the shipment of eggs from this point has reached 83,000 dozen.

The farmers find that barley and alfalfa are quite resistant to alkali, and these crops are grown where other crops would fail because of the excess of soluble salts in the soil. Barley will give greater returns on the clay soils than will alfalfa. Cotton is grown on soils of a wide variety of textures, but it is found that alfalfa will make a crop on the lightest soils when cotton is a failure.

The farming methods characteristic of irrigated sections are practiced in the area. Tractors are used in plowing and preparing the land for crops. Their number, already large, is increasing. Small tractors for the cultivation of cotton are being introduced.

Photo from Univ. of California.

FIG. 1.—VIEW NEAR HOLTVILLE SHOWING GORGE OF ALAMO RIVER.

The perpendicular banks give an excellent exposure of the deposits of the Colorado River, showing their definite stratification. The soil here is the Imperial silty clay.

Photo from Univ. of California.

FIG. 2.—CATTLE GRAZING ON ALFALFA IN WINTER SEASON.

Wintering stock on alfalfa is an important feature of the stock-raising industry in this valley.

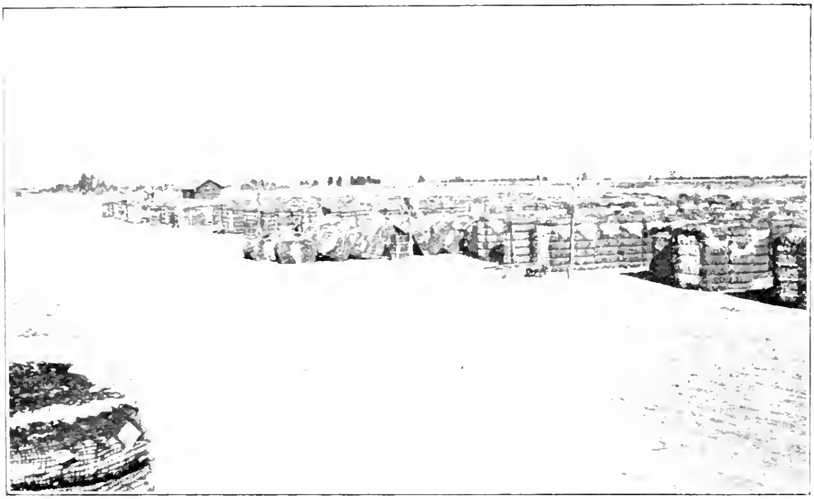

FIG. 1.—COTTON STORED IN YARD AT IMPERIAL.

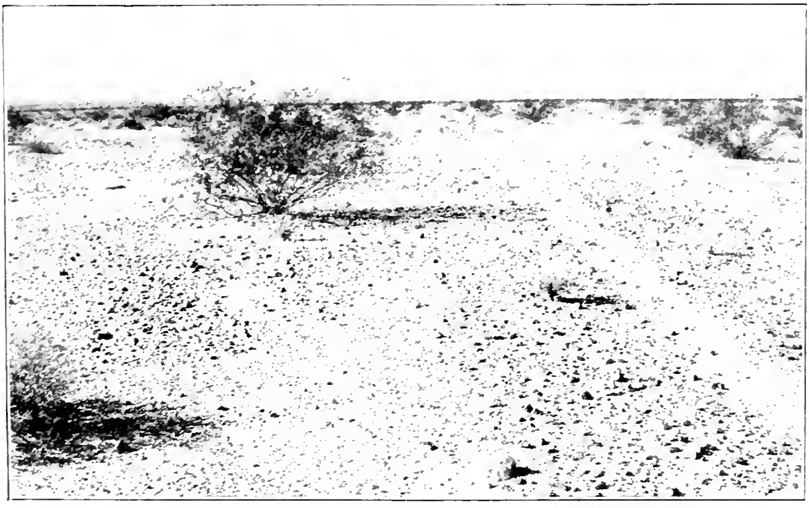

FIG. 2.—TOPOGRAPHY AND CHARACTERISTIC SURFACE GRAVEL (DESERT PAVEMENT) ON SUPERSTITION GRAVELLY SAND.

As a whole the farms are well equipped with stock and the best machinery, but in many cases the farm buildings are of a temporary character. This is especially true of the buildings on rented farms. Barns and sheds for stock are of very open construction or are lacking entirely. The average dwelling house is built mainly with the idea of being cool in summer. Silos have been built in large numbers during the last two years.

So far no definite crop rotations have been worked out by the farmers. The country is quite new, and the soil shows no sign of exhaustion, and silt is continually brought in and deposited by the irrigation water, which has a tendency to renew the soil. No commercial fertilizers are used. In the case of the lighter soils, which are low in organic matter, it is found advisable to use stable or green manures.

In winter there is an abundance of farm labor, but in summer, when there is more work to be done, much of the labor has left the valley to escape the heat. At the time of this survey farm labor in winter was paid from $40 to $55 a month and board, and good milkers received $65 a month. In the summer monthly wages reached $70 or $80 and good milkers were paid from $90 to $100 with board. Day labor in winter received from $2 to $2.50 a day and board, and in summer $3 to $3.50 a day with board.

The price paid for picking cotton at the time of this survey was from $1.25 to $2 a hundred pounds for the short staple; from $1.50 to $2.50 for the Durango; and from $2 to $3.50 for the Pima cotton. The Pima cotton has smaller bolls, making the picking slower and harder.

Most of the farm labor is American. Negroes are employed largely in the cotton fields. Hindus are occasionally employed by the month, but usually prefer to do contract labor, such as picking cotton or heading milo. Mexicans are employed to some extent on the larger ranches and on contract work, but are not usually hired by the month on the smaller farms. Japanese laborers are important in the production of fruit and garden truck, especially muskmelons. They usually work by contract, being rarely employed by the month by Americans. Laborers from southern Europe are becoming an important factor, especially in the dairy and hog business.

Investigations by the farm centers in the area indicate that the average size of the farm is 90 acres. There are no 5 and 10 acre farms, but there are many 40 to 60 acre farms, and there are several farms that contain more than 1,000 acres.

Probably a little over one-half of the farms are operated by the owners, but in the case of cotton apparently more than half the crop

is grown by tenants. Of these tenants, about one-tenth are negroes, one-fifth Hindus, and the rest native whites. Very few Mexicans or Japanese grow cotton.

## SOILS.

The soils of the El Centro area are all so young that they do not differ greatly from the geological formations which make up the surface deposits of the region. Very little progress has been made in soil development. On account of the extreme desert conditions which existed in the region until a very few years ago there was so slight a covering of native vegetation that the accumulation of organic matter in the surface soil was very slight. The surface soils and the subsoils are, in this respect, very much alike. In some cases the surface soil is slightly darker than the subsoil, but this is not universal, so that as a whole it can be said that very little progress in the development of a surface soil with an important constituent of organic matter has been made.

As will be brought out in the description of the soils, the horizons found in them are horizons of deposition rather than those of soil development. They are geological horizons, strictly speaking, rather than soil horizons, although it should be borne in mind in this connection that soils and geological formations are identical at the period of time when deposition of material in a given area has stopped or become slow enough to permit the growth of plants. The stage of development of the soils of the El Centro area has passed but little beyond this most primitive stage.

The presence in the soil of a small, often very small, percentage of soluble salts seems to cause the development of well-defined soil horizons at an early stage in their development. An amount of salts sufficient for such development is unquestionably present in a large part of this area, but on account of the extremely recent deposition of the soil material it is rather difficult to determine in many cases whether the presence of a heavy subsurface horizon is due to deposition or to soil development. It is clear, however, that the development has not gone far enough to warrant the separation of the soils on this basis. They have been differentiated, therefore, on the basis of features that have been inherited from the geological character of the material itself or from conditions of deposition. These features and conditions are described below.

The area occupied by the Colorado Desert is mainly an old structural valley which has been partly filled by accumulations of sediments transported by waters of the short drainage courses having their sources in the surrounding mountains and by the finer sediments carried into it by the Colorado River. The slopes of the surrounding mountains are steep, rugged, and often greatly eroded

and their bases are commonly buried beneath upturned and eroded strata of conglomerate, sandstone, and clay; by masses of recent talus material; or by the short, steep alluvial fans formed at the mouths of the smaller water courses. Beyond these steeper basal slopes, the floor of the desert slopes more gradually toward the lowest part (Salton Sink) of the depression, and presents a rather uniform surface broken only by the presence of an occasional desert stream course, by more or less extensive and prominent masses of wind-blown sand, or by a few occurrences of igneous and old sedimentary material that are now largely buried beneath the detrital material forming the present desert floor.

A large part of this region lies at or below sea level, and the approximate area of this depression is quite clearly outlined for a considerable part of the distance by a low sandy and gravelly ridge which marks the level and the shore line of the last body of water that covered this area for a considerable period of time.

Following the uplift of the mountain masses surrounding this region on the north and west, there was a considerable period of erosion, during which there was deposited along the base of the mountains an extensive area of sands, gravels, and clays. At a considerably later period this mass of sediment, now in the form of more or less thoroughly consolidated conglomerates, sandstones, and clays, was nearly everywhere subjected to a series of movements by which they were greatly tilted, faulted, and folded. In that condition they were subjected to erosion, probably for a considerable period, during which large portions were removed and the remaining portions carved into a typical bad-land topography. A period followed that of the erosion, during which these masses were buried beneath a vast amount of coarser and more recent alluvial material which, at the present time, forms the floor of the desert above the old beach line. Coincident with this deposition of material by the mountain streams, the Colorado River was depositing beds of fine sand, silt, and clay in that part of the basin below sea level, and gradually filled the depression to about its present level. Eventually the Colorado River was diverted toward the Gulf of California by the slow development of a delta ridge, and the waters north of that obstruction gradually disappeared by evaporation. Since that time the Colorado River has occasionally broken through the barrier and flowed into the Salton Sink for short periods, but such overflows have had little effect upon any large areas of the soils already present within the area of this survey.

Since the last great period of deposition of materials about the mountain bases, there has been some local erosion by streams from the eastern front of the Peninsula Range, and in restricted areas

the coarser surface material has been entirely removed and the old upturned sediments exposed and subjected to still further erosion. Examples of this are to be seen on many of the lower slopes of the outliers of the main range of mountains and in the vicinity of Yuha Buttes. In the latter region, not only has the overlying mantle of later unconsolidated sedimentary materials been removed, but the exposed underlying strata of clay and concretionary sandstone have been subjected to erosion, leaving a very rugged area of low relief, almost entirely barren of even the usual desert vegetation.

Within the limits of the El Centro area, none of the igneous formations composing the larger part of the adjacent mountain ranges are found, but the old upturned sediments occur over an area of several square miles, particularly in the southwestern part of the area and locally elsewhere. These form no areas of arable land, and are largely represented upon the soil map by Rough broken land.

The more recent unconsolidated sedimentary materials compose the larger part of the desert soils above the beach line along the eastern and western margins of the area. These sediments form a gently rolling plain sloping toward the central part of the area, the surface of which is broken by occasional desert stream ways and by bodies of wind-blown sand. Below the beach line the materials are largely lacustrine deposits of fine sand, silt, and clay, some of which have, however, been redistributed or modified by winds or streams. Usually these deposits occur in a series of strata extending to unknown depths.

In mapping the soils of the El Centro area, a difficulty not usually found was encountered. Only occasionally is the subsoil composed entirely of material of uniform texture. In most places it is made up of several sharply defined strata of varying textures, rarely with any regularity in vertical distribution. Oftentimes they consist of dovetailing lens-shaped deposits, any one stratum extending but a short distance horizontally. As a result of these irregularities, it is practically impossible to indicate in detail accurately upon the soil map the variations in texture of the subsoils of the various types of soil. The texture of the surface soils, which is indicated by the latter part of the type name, is indicated upon the soil map as closely as possible, taking the scale of the map into consideration, and also the fact that the changes in texture are usually gradual and that a definite boundary as indicated upon the map is usually but an approximation.

The heavier textured materials are compact, locally indurated, are frequently of joint structure, and occasionally show the concentration of calcareous material or alkali salts along cracks and joint planes. Since their deposition the lighter textured materials have

been transported and reworked by wind action, resulting in either the removal of the original material, forming what is known as "blow-outs," or in the building up of accumulations of wind-blown sands, forming extensive areas of Dunesand.

The materials from which the soils of this area are formed are divided into three main groups: (*a*) Old valley-filling materials, (*b*) aeolian or wind-laid materials, (*c*) recent alluvial fan and flood-plain deposits. No residual soil materials from consolidated rocks occur within the limits of the area.

The old valley-filling deposits, which are by far the most extensive, cover more than 66 per cent of the area surveyed. The aeolian materials occupy about 25 per cent of the area, and the recent alluvial materials are of small extent, occupying less than 3 per cent of the area. Each of these groups may include a number of soil series and types that differ in color, texture, structure, and topography, but are alike in their methods of formation. The soil series is represented by one or more soil types alike in essential features of origin, mode of formation, and color, but differing from the others in texture.

*Old valley-filling soils.*—The old valley-filling soils are derived from old alluvial or sedimentary materials. These have undergone more or less modification by weathering and leaching since their deposition. The soil types are normally characterized by rather compact subsoils, in which there may be accumulations of calcium or other minerals, forming cemented hardpans or causing a mottled color. In the present survey little if any cemented hardpan occurs, but some of the subsoils carry thin, irregular seams or layers of material cemented with lime, and in many places the subsoil of the heavier types is so compact that it forms an effective barrier to the movement of moisture. The topography of these soils varies from level to moderately rolling. The drainage is somewhat restricted in the heavier members. Locally these soils support a scattering growth of mesquite trees, but for the larger part they have only a scanty growth of shrubs and bushes. Local areas are devoid of vegetation. The group includes in this survey both the soils derived from old lateral stream-laid and alluvial-fan deposits, lying on marginal slopes of the valley, and the soils derived from lacustrine or lake-laid sediments and associated stream-laid deposits occurring below the beach line. These have been grouped in four series, the Imperial, Holtville, Tijeras, and Superstition.

The surface soils of the types included in the Imperial series are in color prevailingly light brown to chocolate brown with a pronounced pinkish or purplish tint. The subsoil may be either somewhat darker or lighter colored than the surface soils, and is in places slightly mottled with grayish or reddish stains. It is predominantly

heavy and shows shaly or jointed structure and is very compact, but no cementing of the soil particles has taken place. Concentrations of lime are not visible, but the surface soil and subsoil effervesce freely with acid, indicating the presence of appreciable amounts of this material. This series is extensively developed throughout the area under the existing canals and small bodies of it lie on the desert west of the Main West Side Canal. In this area bodies of soil, to a large extent wind blown or wind altered, too small to be shown on the soil map, have been included. The series differs from the related Holtville series by the heavier and more compact subsoil.

The materials of which the Imperial soils are composed consist of sediments deposited by the Colorado River. These have been derived from many different kinds of igneous and sedimentary rocks occupying the drainage basins of that stream and its tributaries.

Three types of the Imperial series are identified in the present survey, the silty clay loam, silty clay, and clay.

The surface soils of the types included in the Holtville series are similar in texture, structure, and color to those of the Imperial series, i. e., they are prevailingly light pinkish or purplish brown to dark chocolate brown in color, heavy in texture, compact, uniformly calcareous, and have a smooth level surface. This series differs from the Imperial series in having a lighter and more open subsoil which is typically a fine sandy loam or fine sand. Heavier textured materials in the subsoil occur only as included thin lenses or layers or in areas of such small extent that they can not be satisfactorily shown upon a map of the scale used in this survey.

The materials of which this series of soils is composed have been derived from a wide range of igneous and sedimentary rocks lying within the watershed of the Colorado River.

Four types of the Holtville series are mapped in the El Centro area, the very fine sandy loam, silty clay loam, silty clay, and clay.

In typical areas the Tijeras series includes types with light grayish red or pale-red to light-pinkish or purplish-brown color. As mapped in this survey, however, there are included areas in which the surface soil is a light-grayish or grayish-brown color, in places approaching that of the Superstition soils. The subsoil is typically of a light brownish red, pale-red, or pinkish color, somewhat lighter than that of the surface soil. Locally the color is pinkish or purplish gray or light grayish brown. The upper part of the soil carries a large quantity of waterworn gravel composed of many different kinds of rocks, and on undisturbed areas this may cover the surface. The mass of the soil, however, contains only a small proportion of gravel. The subsoil is quite compact and in many places heavier than the soil. Both soil and subsoil are highly calcareous, the latter in many places including concretions, seams, or layers of lime. The sub-

stratum occurring from 3 to 10 feet below the surface, normally consists of very old deposits of stratified heavy clay and sandstone-like layers or concretions inclined at a sharp angle, but in some areas the materials below the subsoil are similar to those beneath the Superstition and include coarse sandy deposits of open structure. This series is confined to the southwestern part of the area surveyed and occurs mainly above the old beach line.

The materials giving rise to the soils of this series are old sedimentary deposits. The substratum consists of lacustrine or other water-laid sediments that have been tilted and more or less consolidated since their deposition.

The soils of this series in this survey occur largely on an elevated mesa, in the southwestern portion of the area, and only a few bodies of it lie on the lower parts of the desert. The topography varies from smooth and uniform to somewhat rolling, and is marked by shallow drainage courses. The soils of this area are treeless, and parts of them are devoid of vegetation.

Only one type of this series, the gravelly fine sandy loam, has been recognized in the present survey.

Both soil and subsoil of the Superstition series are light gray or light brownish gray. The soils lack uniformity, owing to the method of their formation. The subsoil, though in places uniform in texture and structure to a depth of several feet, is more commonly made up of variable strata of sand, fine sand, fine sandy loam, and here and there fine gravel. There is no regularity in the arrangement of these strata in the profile. The subsoil is somewhat more compact than the soil, but is characteristically porous and the soils low in power to hold water. Waterworn gravel is nearly always present on the surface. (Pl. II, Fig. 2.) The subsoil is in places gravel free, but in others it occurs usually in thin, irregular strata.

Both soil and subsoil are highly calcareous, and accumulations of lime exist in the subsoils of several of the types, either in irregular strata or in rather large masses. The soils of this series are derived from slightly weathered old valley-filling materials accumulated in alluvial fan and desert-wash deposits. The materials come originally from many different kinds of rocks. In this area the materials include sandy and gravelly deposits occupying bars and beaches marking former shore lines of an inland lake or sea.

Soils of this series occur in the desert east and west of the present irrigated area, the most extensive bodies lying in the latter district.

The surface varies from very uniformly smooth and gently sloping to moderately rolling. It has been subject to local erosion by intermittent streams. Surface drainage is well developed and the subdrainage is excessive. The areas are treeless, the only vegetation being a scattered growth of shrubs and cacti.

In the El Centro area the gravelly coarse sand, gravelly sand, coarse sand, and fine sand of the series are mapped.

*Wind-laid soils.*—Since the disappearance of the former lake the lighter textured surface materials have been subjected to modification by winds of relatively high velocities. The soils, where not protected by some system of cropping, are still being reworked by that agency. The result is that all of the lighter textured materials, with one exception, have either been transported for unknown distances or else modified sufficiently to be classified with wind-laid materials.

The surface soils of the types in this group are either grayish brown or light purplish or pinkish brown. They are loose and incoherent, except where they grade into some of the heavier types of the Imperial or Holtville series. The subsoil is like that of the Imperial or Holtville soils. When of a heavy texture the subsoil shows definite stratification, but this may not be apparent in the lighter textured materials. Owing to this variation in the character of the subsoil the profile is not everywhere typical and there are included variations which, if occurring in large areas, would have been mapped as some other type. Fine waterworn gravel is present in some of the types, either distributed through the soil profile or occurring only on the surface. The topography is seldom smooth. In most places it consists of low dunes and undulations. In many cases the surface material has been removed by the wind, forming what is known as "blow-outs."

Soils of this group in places support a scattered growth of mesquite trees, but over the larger part of this area the vegetation either consists of a few desert shrubs or is entirely wanting.

The material is of loose porous structure and drainage is excessive, except where underlain at shallow depth by compact heavy sediments.

Two series of soils in this group have been mapped in the El Centro area. These are named the Meloland and Rositas series.

The soils of the types included in the Meloland series are light grayish brown to purplish or chocolate brown. The subsoil is identical with that of the Imperial series. The surface is hummocky to rolling, and small isolated areas are sufficiently uneven to be classed as Dunesand. The drainage conditions are variable, depending upon the depth to the heavier subsoil or substratum. Both soil and subsoil are calcareous, and the heavier textured members often carry appreciable quantities of alkali. Three types are shown on the map, the gravelly sand, fine sand, and fine sandy loam.

The types included in the Rositas series have surface soils identical with those of the Meloland series in color, texture, structure, and topography, but their subsoil differs from that of the latter series, and

the separation is made on this basis. The Rositas subsoil consists of sand, fine sand, and fine sandy loam, is permeable, and does not show stratifications, although believed to be either old alluvial or lake-laid sediments as they were deposited by the Colorado River or in the waters of the lake, or of these materials more or less redistributed by winds.

The drainage of these soils is excessive, and it is only along the margins of the types, where they grade into the heavier members of some of the other series or where seepage from the canals occurs, that there is any alkali present.

Five types of Rositas series are mapped in this survey—the Rositas sand, gravelly fine sand, fine sand, very fine sand, and very fine sandy loam.

*Recent alluvial soils.*—The recent alluvial soils include a number of small, irregular areas along the flood plains of New River, and some rather extensive alluvial fans on the desert slopes. In the former location the soils have been deposited by New River since the formation of the present New River wash (1905–6), and are still subject to change through the occasional addition of material deposited during periods of overflow. They are also locally receiving considerable quantities of wind-blown materials from adjacent areas of sand and fine sand soils.

Owing to the small extent of the individual bodies of these alluvial soils along the New River, to the many abrupt changes in texture from place to place, and to the fact that areas are not used for agriculture, no attempt has been made to map them on a textural basis. These areas are therefore shown as Riverwash.

The recent alluvial fan materials occur in the desert in the western part of the survey. The soil derived from these materials is correlated with the Carrizo series.

The Carrizo series includes types with gray to light brownish gray soils and subsoils carrying varying quantities of fine waterworn gravel. In the subsoil the gravel may be present in quantities sufficient to form irregular lenses or strata of some thickness. The areas are subject to overflow at infrequent intervals, and much of the land has no agricultural value. A large part is treeless, but in the immediate vicinity of the channels of some of the streams there is a scanty growth of mesquite and desert shrubs.

In addition to the soils embraced in the series described above three types of a miscellaneous, nonagricultural character have been mapped. These consist of Riverwash, already described, Dunesand, and Rough broken land. The last two will be discussed in connection with the individual types in succeeding pages.

The following table gives the name and the actual and relative extent of the various soils mapped in the El Centro area:

*Areas of different soils.*

| Soil. | Acres. | Per cent. | Soil. | Acres. | Per cent. |
|---|---|---|---|---|---|
| Holtville silty clay | 46,336 | 14.4 | Carrizo sand | 6,912 | 2.1 |
| Imperial silty clay | 40,896 | 12.7 | Holtville very fine sandy loam | 5,952 | 1.8 |
| Meloland fine sandy loam | 35,008 | 10.9 | Rositas sand | 4,544 | 1.4 |
| Holtville silty clay loam | 34,176 | 10.6 | Meloland fine sand | 4,160 | 1.3 |
| Imperial clay | 23,744 | 7.4 | Meloland gravelly sand | 4,096 | 1.3 |
| Imperial silty clay loam | 18,176 | 5.6 | Superstition coarse sand | 3,648 | 1.1 |
| Holtville clay | 17,216 | 5.3 | Tijeras gravelly fine sandy loam | 3,392 | 1.0 |
| Rositas very fine sand | 17,024 | 5.3 | Superstition gravelly coarse sand | 2,880 | .9 |
| Rositas fine sand | 11,584 | 3.6 | Riverwash | 1,856 | .6 |
| Superstition fine sand | 11,264 | 3.5 | Rositas gravelly fine sand | 1,472 | .5 |
| Rough broken land | 9,664 | 2.9 | Rositas very fine sandy loam | 1,216 | .4 |
| Dunesand | 8,960 | 2.8 | | | |
| Superstition gravelly sand | 8,384 | 2.6 | Total | 322,560 | |

IMPERIAL SILTY CLAY LOAM.

The surface soil of the Imperial silty clay loam consists of 6 to 24 inches (and very rarely 72 inches) of a pinkish-brown to chocolate-brown or purplish-brown silty clay loam. The surface soil is underlain by either a silty clay loam or a clay subsoil extending to a depth of 6 feet or more. While the subsoil may consist entirely of either of these materials, uncommonly it is composed of alternating strata of the two textures and thin or irregular lenses and strata of fine sand also may be included. The subsoil varies in color from a pinkish gray or purplish brown to a dark chocolate brown, and is in many places locally mottled with reddish colors and brown. The texture of the surface soil is subject to considerable variation. In the areas of lighter soil the material is friable, tills easily, and seldom forms a hard crust on the surface after irrigation, but where the soil borders the silty or clay types of the series, the surface is often very compact, in places showing a tendency toward an adobe structure. The subsoil is tough and compact throughout, offers considerable resistance to the movement of soil moisture, and when dry has a jointed structure or breaks into small, thin, shaly fragments. The type is free from gravel.

This type is decidedly calcareous, both in the soil and subsoil, but the lime is uniformly distributed, seldom apparent to the eye, and as yet has not caused cementation.

The boundaries drawn between this type and the adjacent soils are arbitrary, as there is no topographic difference on which to base separation, and the textures of the soils intergrade and change very slowly.

With the exception of a few shallow depressions, due to erosion by the flood waters from the Colorado River, the surface of this type is very uniform. The slope, which is largely to the north, is so gradual that the land is apparently level.

This type originally supported a scattered growth of stunted mesquite trees, but the larger part of the native vegetation, which was fairly abundant, consisted of desert shrubs.

The soil is widely scattered throughout the survey for the most part in irregular areas of small extent. The typical areas lie in the central and eastern parts of the survey. In these internal drainage is rather deficient, owing to the heavy texture and compact structure of the subsoil.

The larger part of the type is not, at the present time, suffering from the presence of a high water table, but in small areas waste water, apparently coming from seepage from some of the larger canals, is making its appearance, resulting in an unfavorably moist soil and an accumulation of alkali salts.

Practically all the type carries more than 0.2 per cent of alkali, but where the original position of the alkali has not been influenced by seepage conditions, the larger part of it is found in the heavier textured subsoil. Spotted alkali conditions are not uncommon, but affected areas are seldom of more than one or two acres in extent.

Practically all of this type is under cultivation and irrigation at the present time. Alfalfa, cotton, and corn form the principal crops, and a considerable acreage is devoted to some of the extensively grown truck crops, such as muskmelons, lettuce, and tomatoes.

The following table gives the results of mechanical analyses of samples of the soil and subsoil of this type:

*Mechanical analyses of Imperial silty clay loam.*

| Number. | Description. | Fine gravel. | Coarse sand. | Medium sand. | Fine sand. | Very fine sand. | Silt. | Clay. |
|---|---|---|---|---|---|---|---|---|
| | | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* |
| 575018 | Soil | 0.1 | 0.1 | 0.0 | 1.1 | 13.3 | 56.8 | 28.6 |
| 575019 | Subsoil | .0 | .1 | .1 | .7 | 24.9 | 47.7 | 26.6 |

## IMPERIAL SILTY CLAY.

The Imperial silty clay consists of 12 inches to 3 feet of a light purplish brown to chocolate-brown compact silty clay underlain to a depth of 6 feet or more by a compact tenacious clay. The surface layer of soil, one or two inches thick, is in places of slightly fluffy structure, owing to the presence of an excessive quantity of alkali salts, but otherwise the surface soil is compact throughout. Within

the present irrigated parts of the survey, the soil and subsoil are free from gravel, but in several of the areas of soil of this type in the western and northwestern parts of the area, the surface has a heavy overwash of waterworn gravel. Such areas are indicated upon the soil map by gravel symbols. Because of their small extent, a few areas of the clay and silty clay loam types of the series have been included with this type. They can ordinarily be distinguished in the field by the texture and general appearance of the surface material. The silty clay grades imperceptibly into the other members of the Imperial series, but the boundaries between it and the lighter textured members of other series are generally well defined.

Both the surface soil and subsoil are decidedly calcareous. Apparent accumulations of lime do not occur in the areas under the present canals, but in some of the areas on the desert calcareous material is occasionally concentrated in thin partings between the subsoil strata.

This type is widely distributed over the survey. A large area lies along the Mexican boundary line, west of the channel of New River, and an area of considerable size occurs in and south of the town of Imperial. There are several other bodies a section or more in extent scattered over the eastern half of the survey and areas of a few acres are very common.

The drainage is somewhat deficient, owing to the compact nature and heavy texture of the subsoil. So far there is no widespread damage resulting from irrigation, and the only areas suffering from an excess of water occur where seepage from some of the canals collects.

Overirrigation of this soil may eventually give rise to unfavorable moisture and alkali conditions, but owing to the fact that percolation and capillary movement of moisture take place very slowly and it is almost impossible to get an excess of irrigation water into the soil by ordinary irrigation, and to the fact that the surface evaporation is exceedingly high in this region, resulting in drying out the soil between spring and fall, there is apparently little immediate danger of such a condition arising.

The surface of larger bodies of this type, while apparently level, have a sufficient slope to carry water over the land at a good rate. Many of the smaller areas have this same character of surface, but a considerable number are marked by small hummocks of wind-blown materials and scattered bodies of Dunesand. On the desert, in the northwestern part of the survey, the surface is level to gently rolling and the type in most cases occupies a slightly lower level than the surrounding soil.

Excepting the areas lying above the canals, practically all this type is under cultivation at the present time. Over most of it the

farming conditions appear to be satisfactory, but the crop yields have been low on a few of the areas, owing to the presence of an excessive quantity of alkali.

The tilled crops, such as cotton and corn, are more extensively grown than alfalfa, as the subsoil is too compact for the best results with that crop. Muskmelons and other truck crops are important in certain localities. (Pl. III, Fig. 1.)

The following table gives the results of mechanical analyses of samples of the soil and subsoil of this type:

*Mechanical analyses of Imperial silty clay.*

| Number. | Description. | Fine gravel. | Coarse sand. | Medium sand. | Fine sand. | Very fine sand. | Silt. | Clay. |
|---|---|---|---|---|---|---|---|---|
| | | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* |
| 575014............ | Soil......... | 0.1 | 0.3 | 0.5 | 4.3 | 14.0 | 44.1 | 36.4 |
| 575015............ | Subsoil...... | .1 | .7 | 1.1 | 6.8 | 5.7 | 50.9 | 34.7 |

IMPERIAL CLAY.

The Imperial clay consists of 6 feet or more of a pinkish light brown, purplish-brown, or chocolate-brown compact clay. The larger part of the type is free from gravel, but a thin overwash occurs on some of the bodies on the desert west of the Main West Side Canal. In this region also there are occasional hummocks or thin deposits of wind-blown material over the surface of the clay.

This soil is ordinarily compact throughout the profile, but in a few places alkali salts give rise to a fluffy condition in the immediate surface. Where the texture of the type is heaviest the surface 4 to 6 inches checks like adobe. This characteristic, coupled with the presence of the occasional deposits of sand, has given rise to a peculiar condition, the wind drifting the sand into the cracks and forming irregular nearly vertical seams that may extend to a depth of several inches.

A few small bodies of this type are found in the eastern part of the area, but its principal development is west of the line of the Southern Pacific Railroad. One large area lying west of the town of Imperial extends practically the entire distance across T. 15 S., R. 13 E., and across New River into R. 12 E. Rather extensive bodies are found in the vicinity of the town of Seeley and along the Mexican boundary line in the western part of T. 17 S., R. 13 W. The type also occurs as irregular narrow bodies in the New River gorge or wash, between the areas of Riverwash along the channel of that stream and the bluffs.

The surface of the larger part of this type is exceedingly uniform and is apparently level. The surface irregularities consist of the hummocks of wind-blown material already mentioned, which occupy but local areas, and the winding vertical walled ravines or channels eroded by the action of the flood waters from the Colorado River before New River wash had been fully developed. These erosions are most extensively developed west of Seeley, where they render several hundred acres of land untillable. The narrow areas in the bottom of the New River wash usually have an uneven and eroded surface and are of no agricultural value.

This soil takes up water very slowly, owing to its unusually heavy texture and compact structure, and even after a full season's irrigation the subsoil in many places is dry below a depth of 24 inches. There is but little seepage from the canals where they cross this soil, and where seepage does occur the water is retained near the surface and moves but a short distance before it evaporates.

The average content of alkali in the soil to a depth of 6 feet is usually large, field tests showing more than 3,000 parts per 100,000, or 3 per cent of salts, in many places, while a content of 1 per cent is very common. This alkali may be uniformly distributed throughout the profile, but it is more commonly the case that the surface foot or so does not contain enough to prevent the growth of plants withstanding moderate amounts.

In the body of this type in the south part of the survey, the alkali content averages about 0.5 per cent, and except in a very few local spots it is very uniformly distributed throughout the soil profile. In some fields crops show a spotted condition, but on the whole the growth and yields of cotton and corn have been very satisfactory. Around Seeley and west of Imperial the quantity of alkali in the soil is seldom below 1 per cent, and the general condition of the crops is very spotted. In many cases the plants make a growth of but a few inches before being killed, and sometimes the seed fails to sprout. In the smaller areas scattered throughout other parts of the survey the alkali content varies considerably, but in most of these areas the amount is not too large for crop growth.

Cultivation of this soil is difficult, as it must be handled when in exactly the right moisture condition. If plowed when too wet it turns up in large plastic lumps that are almost impossible to reduce to a good tilth, and when too dry it breaks up into large clods that can not be satisfactorily broken down until after further irrigation. Where the quantity of alkali has not prevented the cultivation of this soil it is largely utilized for cotton and corn. Alfalfa is not a success, as the density of the subsoil prevents the proper development of the root system.

The following table gives the results of mechanical analyses of samples of the soil and subsoil of the Imperial clay:

*Mechanical analyses of Imperial clay.*

| Number. | Description. | Fine gravel. | Coarse sand. | Medium sand. | Fine sand. | Very fine sand. | Silt. | Clay. |
|---|---|---|---|---|---|---|---|---|
| | | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* |
| 575037 | Soil | 0.0 | 0.7 | 2.0 | 14.7 | 6.3 | 32.5 | 41.2 |
| 575038 | Subsoil | .0 | 1.8 | 1.2 | 12.1 | 8.9 | 34.0 | 41.7 |

HOLTVILLE VERY FINE SANDY LOAM.

The surface soil of the Holtville very fine sandy loam is a light-brown or pinkish or light purplish brown slightly micaceous very fine sandy loam. The surface material of this type frequently includes one or more strata, each 1 to 3 inches thick, of compact slightly heavier textured materials, and there is a succession of similar strata at intervals of about 36 inches to an indefinite depth. The structure of the subsoil is slightly compact. Surface and subsoil are both distinctly calcareous. The texture and structure are very uniform throughout the main body of the soil, except where it merges into the surrounding soils, and where small amounts of wind-blown sand have accumulated.

This type occurs as three areas south of Holtville. The larger areas extend about 1½ miles south of Holtville southward on the west side of the Alamo River nearly to the Mexican boundary. The smaller body lies in the southern part of T. 16 S., R. 16 E.

The usual position of the type is somewhat above the general elevation of the surrounding soils, and the areas appearing as low sandy elevations are distinguishable for some distance. An old drainage depression from 20 to 30 feet in depth and extending from the Alamo River in a northwesterly direction across the northern part of T. 16 S., R. 15 E., forms the most prominent surface irregularity within the type. Wind erosion has removed considerable areas of this soil, leaving a part of the type with a miniature badland topography, but much of the surface is uniform or but slightly rolling.

The drainage of the soil is good, but not excessive, owing to the very fine texture of the subsoil and its slight compactness.

A large part of this soil lies slightly above any available gravity supply of irrigation water, and a part of it is being irrigated by pumping from near-by canals. Where the type is under cultivation alfalfa occupies the larger acreage, the grains ranking second. Cotton and corn are seldom grown, and its best adaptation will probably be found in the crops which are now largely grown upon it.

The following table gives the results of mechanical analysis of a sample of the soil of the Holtville very fine sandy loam:

*Mechanical analysis of Holtville very fine sandy loam.*

| Number. | Description. | Fine gravel. | Coarse sand. | Medium sand. | Fine sand. | Very fine sand. | Silt. | Clay. |
|---|---|---|---|---|---|---|---|---|
| | | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* |
| 575048 | Soil | 0.0 | 0.0 | 0.1 | 3.4 | 49.2 | 40.2 | 6.9 |

### HOLTVILLE SILTY CLAY LOAM.

The surface soil of the Holtville silty clay loam consists of 6 to 30 inches of a light purplish brown to a chocolate-brown silty clay loam, underlain by either a fine sand or a fine sandy loam subsoil extending to a depth of 6 feet or more. The subsoil may be uniform in texture, but more commonly consists of alternating strata of fine sand and fine sandy loam. A layer of compact clay is often encountered at the depth of about 6 feet, and this may be several feet in thickness or be only a thin parting in the lighter textured material. As with the silty clay loam of the Imperial series, the surface soil of this type varies considerably in texture, the lighter variations being friable, and often difficult to distinguish from the heavier variations of some of the fine sandy loam types. On the other hand, the soil in some places approximates a silty clay loam in texture. This type is free from gravel.

Both soil and subsoil are calcareous, but no cementing of the material has as yet taken place, the lime being uniformly distributed through the soil mass.

Aside from the presence of small deposits of wind-blown materials lodged around the desert shrubs, and an occasional isolated sand dune, the surface of this type is very uniform. The only prominent surface irregularity within it is the deep wash of New River, which traverses one of the larger bodies of this soil for a distance of several miles.

The most prominent areas are situated in the southern and western central parts of the survey, extending northwest from Calexico along the channel of New River. These are the most prominent areas west of the line of the Southern Pacific Railroad; east of that line the type is confined to widely scattered and rather small areas.

The drainage is generally good, but in a few places, along some of the larger canals, seepage has apparently developed unfavorable moisture conditions. In the larger body of this type along New River, the deep gorge of this stream affords an excellent drainage outlet, and there is but little, if any, danger that the soil here will ever become waterlogged.

Practically all of the surface soil of this type contains small quantities of alkali, and locally amounts sufficient to injure crops. The subsoil in most of the type carries very little alkali, but where heavier subsoil strata are present they usually contain more than 0.2 per cent. Aside from areas where the alkali has been concentrated by seepage waters, the only noticeable occurrences are small spots or areas around the margins of the type, adjacent to soils more strongly impregnated.

Nearly all of this type is under cultivation, largely to alfalfa and cotton. In the extreme eastern part of the area a few small areas have become too wet, apparently through seepage, for cultivation, and have been abandoned.

The following table gives the results of mechanical analyses of samples of the soil and subsoil of the Holtville silty clay loam:

*Mechanical analyses of Holtville silty clay loam.*

| Number. | Description. | Fine gravel. | Coarse sand. | Medium sand. | Fine sand. | Very fine sand. | Silt. | Clay. |
|---|---|---|---|---|---|---|---|---|
| | | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* |
| 575003 | Soil | 0.1 | 0.1 | 0.0 | 0.4 | 6.9 | 67.7 | 24.8 |
| 575004 | Subsoil | .0 | .0 | .1 | 1.3 | 44.8 | 46.6 | 6.9 |

## HOLTVILLE SILTY CLAY.

The Holtville silty clay consists of 12 to 24 inches of a light pinkish or purplish brown to a chocolate-brown compact silty clay, underlain by fine sand or fine sandy loam carrying occasional thin strata of heavier materials. The surface soil is very compact, much of it closely approaching a clay in texture, and small bodies of the clay type of the series too small to be shown upon the soil map are included. Both the soil and subsoil are strongly calcareous.

This type is distributed throughout the survey. The most important areas, lying south of El Centro, average some 6 or 7 miles in length and somewhat more than 1 mile in width. Other areas almost as large occur north and east of Holtville. In the vicinity of Imperial there are a large number of areas each containing a square mile or more.

Where the heavy surface material of this type is of considerable depth, the drainage is slightly deficient, as it is sufficiently compact to prevent the downward movement of the water. Where the surface soil is shallow the drainage is good. In a body of this soil southeast of Holtville in T. 16 S., R. 16 E., some unfavorable moisture conditions have resulted through seepage, but aside from this no ill effects have followed the irrigation of this type.

Practically all the Holtville silty clay carries more than 0.2 of 1 per cent of alkali, with most of it below a depth of 18 inches. Exception must be made of one area about 4 miles northeast of Holtville, where the alkali content is over 1 per cent, with a large part of this in the immediate surface soil. The alkali in this area was present before there was any irrigation in the valley. Attempts have been made to place this land under cultivation, but it is largely unutilized at the present time.

The surface of the larger part of this type is very uniform. In the western part of the survey, where this soil is associated with soils of the Superstition series, the surface in places is marked by accumulations of wind-blown sands.

Some of the areas of this type lie above the present canal systems and are not irrigated. Below the canals nearly all of it excepting the area heavily impregnated with alkali, northeast of Holtville, is under cultivation. Cotton, corn, barley, and alfalfa are all grown, the latter occupying a relatively small acreage. It is well adapted to the first three crops. Muskmelons and lettuce are grown to some extent, but the total acreage of truck crops is small.

### HOLTVILLE CLAY.

The Holtville clay consists of 12 to 36 inches of a light pinkish or purplish brown to chocolate-brown compact heavy textured clay, underlain by slightly lighter colored compact fine sandy loam or silt loam, fine sand occurring in places. The line between the surface soil and subsoil is sharp, and when the subsoil is made up of alternating strata the division between each also is very definite. The surface soil is normally compact, except where the surface layer, 1 or 2 inches thick, is loose and fluffy because of the presence of an excess of alkali salts. Both surface and subsoil contain much lime, which is quite uniformly distributed.

A few small areas of this type are found in the eastern part of the survey, but its principal development is in the west-central part, adjacent to the channel of New River, from about 4 miles south of Seeley northward nearly to the northern boundary.

Much of the original surface of this type was smooth and level, about the only irregularities consisting of the accumulations of wind-blown materials about the desert shrubs. Flood waters from the Colorado River have eroded deep vertical-walled washes in some areas. Several hundred acres have thus been rendered unfit for cultivation.

Owing to the compactness of the surface soil, the internal movement of moisture is slow, and in many places the material is not wet below 2 feet, even following a season's irrigation.

There are some small areas of this soil that contain less than 0.2 per cent alkali, but the most of it carries more than that amount, and a considerable part more than 1 per cent. Field tests show that the larger part of the alkali occurs below a depth of 18 inches.

This type is one of the difficult soils in the area to cultivate. Unless handled exactly at the right time, with respect to the moisture condition, a rough, cloddy surface results, and once in this condition it is extremely difficult to put a field in good tilth.

A large part of the Holtville clay is under cultivation. It is devoted largely to the production of cotton and corn. Alfalfa is seldom grown on this heavy soil. Some of the land has been abandoned because of the unfavorable alkali conditions.

### TIJERAS GRAVELLY FINE SANDY LOAM.

The surface soil of the Tijeras gravelly fine sandy loam where typically developed consists of 3 feet or more of pale-red, brownish-red, or reddish-brown compact fine sandy loam, carrying a large proportion of waterworn gravel. As mapped in this survey, however, considerable areas have a brown or grayish-brown color approaching that of the Superstition series, the two series where adjoining passing gradually one into the other and making it necessary to compromise in placing the boundaries.

The subsoil is normally grayish-brown or light grayish red to reddish-brown, compact, and calcareous clay; but in some of the included nontypical areas it consists of a coarse, porous sandy material extending to 6 feet or more.

The deeper subsoil and substratum is composed of compacted and stratified clay, the layers in many places separated by strata of soft concretionary sandstones. Both the soil and subsoil are calcareous. Concentrations of lime appear in the soil within a few inches of the surface, either as thin sheets or as concretions, and the material is in many places cemented into a soft hardpan. The heavier subsoil is not only highly calcareous, but also carries small amounts of gypsum and alkali incrustations or crystals between the clay strata.

This type is confined to the southwestern part of the area, where it occurs largely on the top of an irregular mesa. A few areas also occur in the same general region on the floor of the desert.

The soil on the mesa has a uniform or gently rolling to steep and eroded surface, the latter on the mesa slopes. The lower lying areas are slightly rolling, and, as a rule, lie slightly higher than the surrounding soils.

The lower bodies of this type probably will have some agricultural value when irrigation water is made available for this part of the area, but the larger mesa area has no present or prospective value, as it lies too high for irrigation.

The following table gives the results of mechanical analysis of a sample of the soil of the Tijeras gravelly fine sandy loam:

*Mechanical analysis of Tijeras gravelly fine sandy loam.*

| Number. | Description. | Fine gravel. | Coarse sand. | Medium sand. | Fine sand. | Very fine sand. | Silt. | Clay. |
|---|---|---|---|---|---|---|---|---|
| | | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* |
| 575028 | Soil | 2.1 | 7.7 | 4.3 | 28.6 | 11.8 | 26.7 | 18.9 |

SUPERSTITION GRAVELLY COARSE SAND.

Both the soil and subsoil of the Superstition gravelly coarse sand consists of a mixture of light-gray or light brownish gray very coarse sand and fine waterworn gravel. The larger part of the gravel is formed of quartz particles about the size of rice grains, but locally, especially along the beach line in the eastern part of the area, there is a noticeable admixture of coarser, dark-colored gravel.

Both surface soil and subsoil are calcareous. Along the line of the beach accumulations of lime are not visible, but in the apparently older areas in the extreme western part of the area concentrations occur in the form of large irregular concretions, in both soil and subsoil. In a number of places the removal of some of the surface soil by winds has left these concretions protruding a few inches above the surface.

The larger part of this type occurs as nearly continuous low ridges extending across the area from north to south on both sides of the valley. These ridges mark the line of the beach of the last body of water and represent the coarser material thrown up by the waves along the shore. The more elevated bodies in the extreme western part of the area represent either an old beach line, now nearly obliterated, or else bars formed in shallow water. In general, the surface of the type is rolling.

The type Superstition gravelly coarse sand has no agricultural value, both its coarse texture and uneven topography being unfavorable.

SUPERSTITION COARSE SAND.

The surface soil of the Superstition coarse sand consists of 6 to 12 inches of a light-gray to light brownish gray coarse sand, in places carrying a considerable admixture of fine gravel occurring mainly on the surface. The subsoil is similar to the surface soil in texture and structure, but is normally slightly lighter in color. Stratification occurs in both soil and subsoil, but the various layers ordinarily are not sharply separated. The soil is uniform in texture and structure, the only noticeable variation in the surface material consisting of

accumulations of wind-blown materials, either around shrubs or in larger isolated dunes.

The type occupies a level to gently rolling surfaced mesa in the extreme southwestern part of the area.

None of this type is under irrigation, and owing to its elevation it probably will be many years before water will be available. The surface soil and subsoil are very porous and low in organic matter, and a large amount of water would be required for any crop that might be grown. Alfalfa would probably be found better adapted to this soil than would the shallower rooted crops.

### SUPERSTITION GRAVELLY SAND.

The surface soil of the Superstition gravelly sand consists of 6 to 18 inches of a light grayish brown or light brownish gray sand, which contains varying quantities of fine to medium, waterworn gravel. The surface soil always carries a rather large proportion of gravel, and there is usually an appreciable amount of it in the subsoil though locally there may be none. The color of the subsoil is similar to that of the surface soil. The texture and structure are extremely variable, ranging from pure gravel to rather heavy loam. Over the larger part, however, it is a light-textured sandy loam or fine sandy loam. In most places it is stratified, but very irregularly, strata of any given material ordinarily extending but short distances and varying greatly in thickness.

Both the surface soil and subsoil are high in lime. The former seldom carries any visible concentrations, but the subsoil normally contains thin irregular deposits of calcareous material between the different strata or in larger concretionary masses, irregularly distributed. In many places the coarser gravel has a thin whitish coating of lime.

Variations from the above description occur along the margins of the various areas either as the result of a local reworking or of zones of gradation between this and adjacent types. The most notable variation of the latter sort is along the contact of bodies of this soil and the Rough broken land in the northern part of T. 16 S., R. 11 E. The Rough broken land here consists of a narrow eroded belt between this type and the lower bodies of recent alluvial soils; and, in such locations heavy-textured stratified materials, such as occur in the Imperial series, are locally present in the subsoil.

The larger part of this type lies in the western part of T. 16 S., R. 11 E., west of the old beach line. A few smaller areas occur below that line, and also in the eastern part of the area just below the old beach line in T. 15 S., R. 16 E.

In a few localities there is no distinct line of demarcation between this type and the adjacent soils. It usually occurs, however, as level

to gently rolling areas, slightly above the recently formed soils, from which it is separated either by narrow belts of Rough broken land or by nearly vertical slopes or terraces a few feet high, and is thus easily distinguishable. The drainage is excessive.

The soil is, as a whole, free from alkali, the latter, where present, occurring in the deeper subsoil only within a very narrow area along the boundary between this type and bodies of the heavier soils of the Imperial series.

Very little of this type is under cultivation at the present time, as only the narrow body in the northeastern corner of the area is below the present canal system. The native vegetation consists of a scattered growth of creosote bush and other low desert shrubs. The topography is favorable to irrigation and cultivation and the type should be well adapted to the growing of alfalfa when water is made available.

The following table gives the results of mechanical analyses of samples of the soil and subsoil of the Superstition gravelly sand:

*Mechanical analyses of Superstition gravelly sand.*

| Number. | Description. | Fine gravel. | Coarse sand. | Medium sand. | Fine sand. | Very fine sand. | Silt. | Clay. |
|---|---|---|---|---|---|---|---|---|
| | | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* |
| 575026 | Soil | 5.6 | 17.0 | 10.1 | 38.4 | 11.6 | 11.1 | 6.3 |
| 575027 | Subsoil | 6.1 | 11.1 | 6.0 | 50.7 | 15.7 | 6.7 | 3.6 |

## SUPERSTITION FINE SAND.

The surface soil of the Superstition fine sand consists of 6 to 18 inches of light brownish gray fine sand, containing a relatively large proportion of medium and coarse sand material. The soil passes gradually into the subsoil, which is a light-gray or light brownish gray light-textured compact fine sandy loam, carrying in places considerable quantities of fine waterworn gravel. In places it may consist of varying strata of gravel, coarse sand, fine sand, and sandy loam. Stratification occurs also in the surface soil. The character of the immediate surface material in many places has been changed by the action of the wind, either through the removal of the lighter textured materials, or by the development of hummocks and isolated bodies of sand. In the east central part of T. 15 S., R. 11 E., one area of this type carries a large proportion of waterworn gravel on the surface, and the texture of the surface soil approximates a fine sandy loam. The areas of this type in T. 15 S., R. 16 E., east of the East Side High Line Canal are also somewhat heavier in texture than typical. Accumulations of surface gravel are indicated on the soil map by means of symbols.

The surface soil is slightly calcareous, but is not cemented. The subsoil is high in lime, compact, carries thin irregular seams of calcareous material throughout the deeper part, and contains lime-coated gravel. Locally the subsoil is firmly cemented, but softens soon after the application of water.

This type is quite clearly separated from the old beach-line soil (Superstition gravelly coarse sand) by a distinct difference in elevation, but the line of separation between the Superstition fine sand and the other types of soil is very indistinct, and many of the boundaries are arbitrary.

This type is most extensively developed in the western part of the area, largely between the old beach line and the Main West Side Canal. Only one small area lies east of the canal, and only a few areas above the old beach.

The surface is level to gently rolling, and the only noticeable irregularities consisting of isolated sand dunes and accumulations of wind-blown sand around the bases of shrubs.

The type is well drained and free from alkali, except in the small area east of the canal, where seepage has caused a high water table.

None of the type is under cultivation at the present time. The area under the canal formerly was in alfalfa, but the unfavorable moisture and alkali conditions have caused it to be abandoned. When water is available for this type, it will probably be found better adapted to alfalfa than to the tilled crops usually grown in the valley.

### MELOLAND GRAVELLY SAND.

The surface soil of the Meloland gravelly sand consists of 6 to 36 inches of a light grayish brown to light-brown, or slightly purplish brown slightly sticky or loamy sand, containing a considerable quantity of small waterworn gravel. The subsoil is brown to purplish or chocolate brown in color and consists of a compact silty clay loam, silty clay, or a clay extending to a depth of 6 feet or more, though thin lenses or layers of lighter textured sediments may be included. The surface material has been reworked to a varying extent by the wind, resulting either in the removal of the finer material and a surface concentration of gravel or in the development of small dunes.

The surface of the Meloland gravelly sand is gently rolling to hummocky. The drainage is slightly deficient. The soil is ordinarily free from alkali, but the subsoil in most places carries considerable quantities.

This type occurs mainly in the northwestern part of the area. It is entirely above the present canal. Parts of it have been leveled and checked, but none of it is under cultivation. It will probably be found well adapted to alfalfa and the various tilled crops, the former

particularly in those districts where the heavier subsoil lies at a considerable depth.

The following table gives the results of mechanical analyses of samples of the soil, subsoil, and lower subsoil of the Meloland gravelly sand:

*Mechanical analyses of Meloland gravelly sand.*

| Number. | Description. | Fine gravel. | Coarse sand. | Medium sand. | Fine sand. | Very fine sand. | Silt. | Clay. |
|---|---|---|---|---|---|---|---|---|
| | | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* |
| 575032 | Soil | 5.1 | 14.4 | 7.4 | 45.9 | 16.9 | 0.9 | 9.4 |
| 575033 | Subsoil | 2.7 | 4.2 | 2.3 | 14.9 | 9.4 | 30.6 | 35.8 |
| 575034 | Lower subsoil | 8.4 | 14.0 | 4.8 | 24.2 | 7.9 | 18.8 | 22.0 |

MELOLAND FINE SAND.

The Meloland fine sand consists of a loose incoherent yellowish-brown or light grayish brown fine sand extending to a depth of 12 to 30 inches, underlain by compact purplish or chocolate-brown or brown silty clay loam, silty clay, or clay.

The subsoil may extend to a depth of 6 feet without change, or may consist of interstratified beds including locally material of lighter texture. In typical areas the fine sand surface soil extends to the depths stated above, but owing to the action of the wind has heaped the surface soil into dunes from 6 to 10 feet in height, exposing the heavy subsoil materials in the intervening depressions.

Typical areas of this type are developed only in T. 15 S., R. 12 E. The duny areas, which contain but a few acres each, occur rather widely distributed throughout Ts. 15 and 16 S., R. 12 E.

The subdrainage of this type is slightly deficient and the subsoil carries some alkali. The surface soil is free from excessive alkali accumulations.

Only a few acres of Meloland fine sand have so far been leveled for irrigation and none of it is under cultivation. Water is available for but a small part of the type, as it lies largely above the present canals. Under irrigation the areas, where the heavier subsoils are at a considerable depth, will be suited to the growing of alfalfa, and those of more shallow soil to grains or cotton.

The following table gives the results of mechanical analyses of samples of the soil and subsoil of the Meloland fine sand:

*Mechanical analyses of Meloland fine sand.*

| Number. | Description. | Fine gravel. | Coarse sand. | Medium sand. | Fine sand. | Very fine sand. | Silt. | Clay. |
|---|---|---|---|---|---|---|---|---|
| | | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* |
| 575039 | Soil | 0.0 | 1.6 | 8.7 | 69.3 | 10.6 | 3.6 | 6.2 |
| 575040 | Subsoil | .0 | 1.7 | 2.2 | 7.9 | 5.6 | 12.8 | 69.9 |

### MELOLAND FINE SANDY LOAM.

The Meloland fine sandy loam is typically a light-brown to a light pinkish or purplish brown friable fine sandy loam, from 12 to 36 inches deep, underlain by a silty clay loam, silty clay, or clay, extending to 6 feet or more. The predominating texture of the subsoil is silty clay loam or silty clay, but any of the textures mentioned may occur in well-defined strata, and these irregular pockets or layers of lighter textured sediments may be included locally. The heavier strata are compact. The color of the subsoil is predominantly a brown, but may be brown mottled with either reddish or grayish stains.

Several areas of this soil, particularly west of Holtville, approach a loam in texture, and to the south of Holtville several areas resemble the very fine sand of the Rositas series in that the subsoil occasionally carries thin strata or seams of lighter textured materials.

Both soil and subsoil of the Meloland fine sandy loam are calcareous, but no cementation has taken place and no concretions or other accumulations of lime have developed.

Meloland fine sandy loam is widely distributed throughout the area, except in the northwestern quarter. An important area lying about 5 miles east of El Centro has an extent of some 10 square miles. Another is mapped about 2 miles east of Holtville. Other areas of varying sizes are associated with soils of the Imperial and the Holtville series.

In its natural condition this type was slightly hummocky, and locally marked by isolated bodies of Dunesand. Most of the type has been leveled for irrigation and has a smooth, gently sloping surface.

The drainage of the soil is slightly deficient, and accumulations of underground or seepage water, particularly in the southeastern part of the area, are developing in local areas. Narrow areas of soil along the canals already have become too wet for cultivated crops.

The heavier subsoil material of this type in most places contains more than 0.20 per cent alkali, and the quantity in many places is relatively large. The surface soil is free from alkali, except where seepage or a high water table has caused its concentration in this part of the profile.

Alfalfa and grains are the principal crops on this type. (Pl. III, fig. 2.) The former is apparently better adapted to those bodies where the heavy subsoil lies several feet below the surface. The grains do best where the surface soil is relatively shallow.

The following table gives the average results of mechanical analyses of samples of the soil and subsoil of the Meloland fine sandy loam:

*Mechanical analyses of Meloland fine sandy loam.*

| Number. | Description. | Fine gravel. | Coarse sand. | Medium sand. | Fine sand. | Very fine sand. | Silt. | Clay. |
|---|---|---|---|---|---|---|---|---|
| | | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* |
| 575041, 575043 | Soil | 0.0 | 0.2 | 0.4 | 46.5 | 30.7 | 12.2 | 9.8 |
| 575042, 575044 | Subsoil | .0 | .0 | .1 | 17.3 | 26.9 | 35.0 | 20.6 |

## ROSITAS GRAVELLY FINE SAND.

The surface soil of Rositas gravelly fine sand is a light-brown, somewhat compact but pervious fine sand, containing a large percentage of small waterworn gravel. The surface soil ranges in depth from 6 to 12 inches, and is underlain by an incoherent yellowish-brown fine sand extending to a depth of 6 feet or more. Both the surface soil and subsoil are calcareous, but no concretions or segregated deposits of calcareous material are present.

This type is restricted to a few small areas in the northeastern corner of the area, east of the old beach line. This is gently rolling to slightly hummocky. It is slightly lower than that of the old beach line, but has about the same elevation as other adjacent soils.

The materials composing this type are derived from the old sedimentary deposits that form the higher desert slopes east of the irrigated part of this valley. Since their deposition, the surface, which is but scantily covered with vegetation, has been subjected to the force of the winds for a very long period, and there has been both a reworking and a removal of the original material. As a result the areas are dotted with mounds and marked by occasional larger dunes. Another result of the reworking has been the concentration of gravel in places on the surface, so that typical desert pavement has developed. In such areas the larger part of the surface material to a depth of 2 or 3 inches may consist of gravel. Drainage is somewhat excessive.

None of this type is under cultivation at the present time, as it lies entirely above the present supply of irrigation water. The native vegetation is largely creosote bush. Under irrigation the land should prove well adapted to alfalfa.

## ROSITAS SAND.

The Rositas sand consists of 6 feet or more of a slightly pinkish, yellowish, or light grayish brown medium-textured incoherent sand, of low organic-matter content, containing in many places small

shells and calcareous concretions. The only variation in the character of this type is around the margins of the bodies where it grades into a heavier member of the Imperial series, and in such locations a compact heavy subsoil is present at depths below 3 feet.

The surface is hummocky, the material being subject to movement with every wind. It is identical in formation with Dunesand, the only difference between the two types being in the relatively smoother topography of this soil, which makes it possible to level it for irrigation and cultivation.

This type is confined to the western part of the area, in the vicinity of the Main West Side Canal, in Ts. 16, 16½, and 17 S., and largely in R. 12 E.

Alfalfa occupies the largest part of the area now under cultivation. Some small grain, cotton, and corn are also grown, but the tendency is to confine those crops to the soils of series having heavier subsoils.

### ROSITAS FINE SAND.

The Rositas fine sand consists of 6 feet or more of a light yellowish brown, or light grayish brown incoherent fine sand, but as mapped in this survey the soil in small areas, most commonly in the zone of gradation into the heavier textured soils of the Imperial series, is less than 6 feet deep, and a heavier subsoil stratum occurs. In its natural condition the surface of this type is marked by hummocks and ridges of wind-blown materials, which is even now more or less unstable. The type is similar to the soil mapped as Dunesand, except in the matter of unevenness of surface, the Rositas areas showing less relief.

This type is developed almost exclusively in the eastern and western parts of the area, adjacent to the East Side High Line Canal, and the Main West Side Canal, where it is associated with the very fine sand of this series and with Dunesand. Outside of these localities, the only notable body is found between the Alamo River and the Ash Canal, in Ts. 16 and 17 S.

This type is devoted largely to alfalfa, to which it is apparently better adapted than to such tilled crops as cotton and corn, for the reason that it affords conditions favorable to the extensive root development of that plant. Alfalfa is also a desirable crop in that it forms a permanent cover for the soil, thus preventing the drifting of the surface material that takes place in areas planted to annual crops.

The following table gives the results of mechanical analysis of a sample of the soil of the Rositas fine sand:

*Mechanical analysis of Rositas fine sand.*

| Number. | Description. | Fine gravel. | Coarse sand. | Medium sand. | Fine sand. | Very fine sand. | Silt. | Clay. |
|---|---|---|---|---|---|---|---|---|
| | | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* |
| 575024 | Soil | 0.0 | 0.0 | 0.3 | 54.5 | 36.0 | 4.6 | 4.4 |

ROSITAS VERY FINE SAND.

The Rositas very fine sand consists of 6 inches to 3 feet of a somewhat loamy light grayish brown to light-brown very fine sand, underlain to a depth of 6 feet or more by incoherent sand, fine sand, and permeable fine sandy loam. Both soil and subsoil are slightly calcareous, but no local concentrations of lime occur.

Considerable variation in both the texture and structure of the soil and subsoil occurs in marginal areas of the type, the former merging gradually into the adjacent soils and the latter containing in many places strata of heavier materials.

Virgin areas of this soil have either a slightly rolling surface, with small accumulations of wind-blown materials around the bases of shrubs, or a decidedly rolling and ridged topography, locally dune-like. Within the irrigated districts of the area, which have been leveled, there is commonly no surface difference between this and the adjacent types, except locally where there are small areas of wind-blown sand. (Pl. IV, Fig. 1.) Within the areas of this type the wind in places has removed the soil, forming what are locally known as "blowouts." Some of the smaller "blowouts" have been filled in and are now cultivated, but the surface of some of the areas is so irregular that no attempt has been made up to the present time to reclaim them. A notable example of this condition is in the district about 3 miles southeast of El Centro.

A few areas of this type, in the vicinity of the Main West Side Canal and southward from Dixieland, constitute practically the extent of this soil in the western half of the area. East of the line of the Southern Pacific Railroad there are a few small areas in T. 15 S. The largest areas occur south and southeast of Holtville and southeast of El Centro, and a number of smaller bodies are distributed throughout the southeastern part of the area.

The drainage of this type is naturally good to slightly excessive, but there are a few places in the vicinity of the larger canals where the soil has been affected by seepage or by a rise in the level of the water table.

Practically all this soil contains alkali in quantities ranging from 0.2 to 1 per cent, the salts in most cases being uniformly distributed throughout the soil profile. In the immediate vicinity of the larger canals, where some seepage occurs, there may have developed an alkali crust, below which the quantity of alkali may be hardly appreciable. As with all the soils of the area, excepting the wind-blown sands and fine sands, there are here and there spots, in many cases but a few feet in diameter, where the quantity of alkali is sufficient to prevent the growth of plants, but which are of too small extent to be shown on the soil map.

Nearly all this type is under cultivation, the largest uncultivated body being that in the "blowout" region southeast of El Centro. Most of the crops common to the region are grown. There is a tendency to use the areas with the lighter subsoil for alfalfa and to restrict the tilled crops to areas in which the heavier subsoil occurs.

The following table gives the results of mechanical analyses of samples of the soil and subsoil of the Rositas very fine sand:

*Mechanical analyses of Rositas very fine sand.*

| Number. | Description. | Fine gravel. | Coarse sand. | Medium sand. | Fine sand. | Very fine sand. | Silt. | Clay. |
|---|---|---|---|---|---|---|---|---|
| | | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* |
| 575021 | Soil | 0.0 | 0.1 | 0.1 | 36.2 | 48.6 | 12.7 | 1.9 |
| 575022 | Subsoil | .0 | .1 | .2 | 41.3 | 44.4 | 7.0 | 7 1 |

## ROSITAS VERY FINE SANDY LOAM.

The soil and subsoil material of the Rositas very fine sandy loam to a depth of 6 feet or more, is a light grayish brown very fine sandy loam of friable structure though rather heavy texture, the proportion of silt being relatively large. It is uniform in texture throughout the soil profile, except that in the lower part it becomes somewhat compacted and therefore less pervious. It contains a fair amount of organic matter and is easily cultivated. The soil contains enough alkali to have a serious effect on its use.

Only one area of this type is found in the El Centro survey. This is situated about 5 miles northeast of Holtville on the east side of the Main East Side Canal. Viewed as a whole the area is nearly level, but in detail the surface, before it has been leveled, is very uneven, being thickly settled with circular dunes, ordinarily 5 to 8 feet high, but in some places attaining a height of 10 or 12 feet. The soil in the flats or hollows between the dunes is a trifle heavier than the soil of the dunes.

There is no erosion in this soil and the drainage is naturally rather poor. Waste irrigation water from higher lying ground has been al-

lowed to flow across it, keeping part of it quite wet. After leveling it is well suited to irrigation.

The dunes support a sparse growth of mesquite and other desert plants.

Up to the present most of the type remains in its virgin condition, owing apparently to the high cost of leveling the dunes and to the uncertainty of crops on a soil of such a high alkali content. Part of it, that having the least alkali, is being leveled and utilized for crops, the yields of which are low to moderate.

### CARRIZO SAND.

The surface soil of the Carrizo sand, which varies from 6 to 12 inches in depth, is a light-gray or light brownish gray sand, ranging in texture from coarse to rather fine, and with or without small quantities of small waterworn gravel. The soils of different textures occupy very small areas and it is not possible to differentiate them on a map of the scale used in the present survey. This has caused their grouping under the one name Carrizo sand. The subsoil, the color of which is similar to that of the surface soil, is normally a rather coarse sand carrying considerable waterworn gravel, the proportion of the latter increasing with depth. Both soil and subsoil contain small amounts of lime uniformly distributed, but no concretions or other accumulations of lime or cementing of the soil material by lime were noted in the course of the survey.

The material of this soil has been deposited by several desert washes in the western part of the area. The discharges of these streams are intermittent and exceedingly irregular, and with every flow of water the soil is subject to alteration in texture and structure either by erosion, deposition, or a reworking of the material already in place.

This type occurs in long, narrow bodies, somewhat depressed below the level of the adjacent soils, and occupying local flood plains of desert streams, or as rather extensive gently sloping alluvial fans.

None of this soil is under cultivation at present, and its possible agricultural value is low. In the northern part of T. 16 S., R. 11 E., the soil occupies the broad floor of a desert wash, which at frequent and irregular intervals may be completely covered with water for brief periods. In the other bodies of this soil the streams have developed no permanent channels, but have laced the surface with a network of shallow, poorly defined courses. The discharge of these streams would necessarily have to be confined to permanent channels before the land could be used, and the construction of such works and their maintenance would be an expensive undertaking. In addition, the soil would require large quantities of irrigation water, owing to the open, porous subsoil. Under irrigation this soil would

probably be better adapted to alfalfa than to the grains or tilled crops commonly grown in this region.

### RIVERWASH.

The material mapped as Riverwash in the El Centro area is not typical, in that it is free from gravel and coarse sand and consists of a succession of thin strata composed of fine sand, silt, and clay, resting upon a deep substratum of compact clay.

The type is located within the narrow flood plain of New River, where it has been deposited since the recent erosion of the present valley of that stream. The soil is subject to continual alteration and reworking during overflow of the river, and parts of it are being slowly buried beneath accumulations of materials carried by the wind from the higher lands. The drainage is deficient.

Owing to the unfavorable drainage conditions, the danger of overflow, and the impracticability of economically reclaiming these lands under present conditions, this type has no immediate agricultural value, and its only value lies in the scanty pasturage it affords.

### ROUGH BROKEN LAND.

Rough broken land consists of soil materials representing a variety of soil series, the topography of which is too uneven and broken to allow their use for agriculture.

In this survey Rough broken land includes the eroded areas in the western part of the survey in the vicinity of the Yuha Buttes and around the margins of the irregular mesa occupied by the Tijeras gravelly fine sandy loam. It also comprises narrow bodies consisting of the slopes of some of the valleys of the larger desert streams and the rough and eroded areas of the Superstition Mountains lying within the survey. It rarely occurs in any other parts of the area.

### DUNESAND.

The type Dunesand consists of 6 feet or more of fine or very fine sand, occurring in hummocks and dunes so large that they can not be economically leveled and thus made suitable for irrigation and cultivation. These dunes usually are devoid of vegetation, except for small desert shrubs around their bases, or partly buried but still living mesquite trees, arrowweed, or creosote bushes.

Dunesand is most extensively developed east and west of central irrigated parts of the area, where it occurs either as isolated dunes, or as nearly continuous areas of drifting sand. Within the central part of the area, south of Holtville, there is one rather extensive area of Dunesand, but its usual occurrence is as smaller bodies scattered through areas of other types of soil. Practically all of this material is unstable and with every severe storm the dunes move

a distance of several feet. This movement is largely to the east, and is slowly burying the native vegetation and the cultivated crops in front of it. The land is not utilized and has no agricultural value.

## IRRIGATION.

The possibilities of irrigating this region were apparently first realized by a western traveler in 1849, and 10 years later the California Legislature passed an act ceding all the State rights in the land to an individual who proposed to place the land under irrigation. The unsettled conditions just prior to the Civil War commanded the attention of the United States and the consent of the Federal Government to the above arrangement could not be obtained. The matter of irrigating these lands again attracted some attention at the time of the construction of the Southern Pacific Railroad from Yuma to Los Angeles, in 1879, but it was not until about 1892 that the first field survey was made. In 1900 work was begun on a diversion and distributing system by the California Development Co., and in 1902 the first water was available for some of the lands north of the international boundary. The rapidity of the development in this region is evident from the fact that in 1909, seven years after the first water was available, there had been constructed main and lateral canals with a total length of 1,007 miles and 190,711 acres of land had been brought under irrigation.[4] Four years later (1913) there were about 264,000 acres under irrigation.[5]

The development of this project was continued by the California Development Co. for several years. Financial difficulties resulted in the acquiring of the system by the Southern Pacific Railroad Co., and later it was purchased by the farmers and is now owned and controlled by them under the name of the Imperial Valley Irrigation District. This organization confines itself solely to maintaining the diversion works and main distributing canals, and with distributing water to the several mutual water companies, the delivery of water to the consumers being effected through the latter organizations. These pay 50 cents per acre-foot (measured at the point of diversion) and the water is delivered to the users at the rate of 50 cents per acre-foot for each 24 hours, in addition to which annual assessments are levied against the lands in each district to meet the expenses of maintaining an administrative force, maintaining canal structures, and removing deposits of silt from the canals. (Pl. IV, Fig. 2.)

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[4] U. S. Census, 1910.

[5] W. S. Paper No. 395, p. 44, U. S. Geological Survey.

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FIG. 1.—IMPERIAL SILTY CLAY PREPARED FOR PLANTING TO MUSKMELONS.

FIG. 2.—ALFALFA GROWN AS A SOILING CROP ON MELOLAND FINE SANDY LOAM.

This crop was ready to cut January 5.

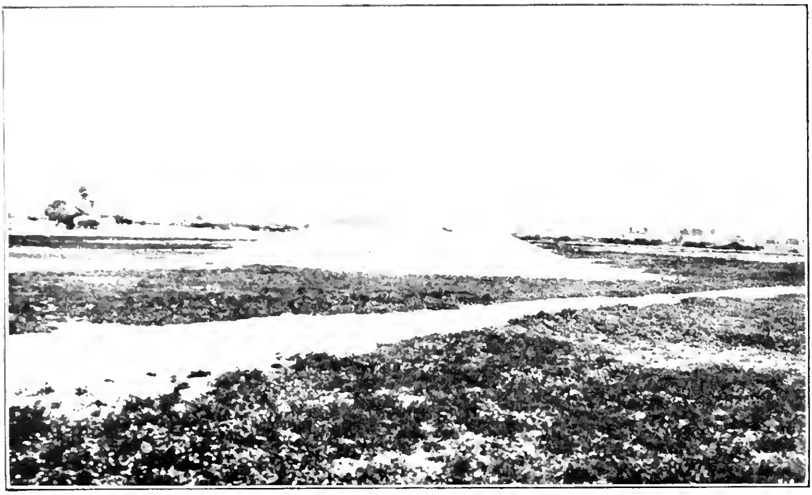

Photo from Univ. of California.

FIG. 1.—ROSITAS VERY FINE SAND NEAR HOLTVILLE.

With the exception of the one large dune in the foreground, which has been left on account of cost of leveling, this area has been leveled for irrigation. The crop is alfalfa.

FIG. 2.—VIEW LOOKING DOWN ROADWAY, SHOWING WALL OF SILT DEPOSITS REMOVED FROM IRRIGATION CANAL ON LEFT.

Removal of this material is a troublesome problem in connection with irrigation in this valley.

All the water used for the irrigation of this area is supplied by the Colorado River, which has a watershed of about 244,000 square miles, and a mean annual run-off of about 17,000,000 acre-feet.[6]

The water is diverted from the Colorado River at the Hanlon Heading, a few hundred yards north of the international boundary line, and about 7 miles by river below Yuma, Ariz. The main canal enters Mexican territory and extends westward for about 50 miles to Sharps Heading, where several smaller canals carry water north across the international boundary line to the eastern and central parts of the El Centro area and adjacent lands on the north. Other canals distribute water to the western side of the valley.

Difficulties in successful diversion, owing to the unstable nature of the channel of the river, have at times resulted in a shortage of irrigation water and measures are now being taken to provide for a permanent and adequate supply.

Late in 1904 an unusually heavy flood in the Colorado River cut through the heading, and in the summer of 1905 and 1906 the entire flow of that stream turned northward and flowed into the Salton Sink. This break in the river bank was closed in 1906, and since that time the flood waters of the river have flowed to the Gulf of California.

The records of delivery of water during 1915 show that about 75 per cent of the annual amount was supplied from April to September, inclusive. During the winter months the delivery was about 4 per cent of the annual amount, the water at that time of the year being used largely for stock and domestic purposes. During that year, when there was a shortage of water during some of the summer months, the duty of water throughout the district was reported to have been 2.72 acre-feet.

The amount of water needed for crops will vary with the crop and the physical character of the soil, so that figures for any given part of the valley may be totally useless if used as a basis for the calculation of the needs of another part. The following data give some indication of the amounts of water applied in the culture of the various crops. The superintendent of Water Co. No. 1 states that the average amount of water applied per acre to the different crops in 1912 was as follows:[7] Alfalfa, 4.19 acre-feet; corn, 2.18; muskmelons, 1.62; and barley, 1.00. With the exception of alfalfa, all the crops occupy the ground for but a part of the year; this explains in part their smaller requirements. Water Co. No. 7 reported in 1907 that alfalfa required from 3.50 to 4.00 acre-feet.

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[6] U. S. Geological Survey, W. S. Paper No. 395, p. 23.

[7] Fourth Biennial Report, Dept. of Engineering, State of California. 1912 to 1914.

Tilled crops such as cotton, corn, and truck crops are irrigated by the furrow method; alfalfa, grain, and grass fields are divided into long narrow shallow basins locally known as "lands," which are flooded at proper intervals.

In considering the possible future results of continued irrigation on the soils of this area only a very general statement can be made owing to the ever variable nature of the subsoil conditions, and time may prove that any present prediction will fall short of the actual conditions that may develop.

For the purpose of discussion the soils may be divided into a number of general groups. The first of these would include the soils of the Imperial series and those bodies of the types of the Meloland series where the surface soil is very shallow. In these soils the characteristic feature of the subsoils is a heavy texture ranging from silty clay loam to heavy clay, with which is associated a condition of very compact structure. Such soils permit only a slow gravity or capillary movement of moisture and ordinarily take up but little water, and in many cases it has been found that after a season's irrigation the subsoil was still air dry below a depth of 24 inches. It has also been found in fields which had been irrigated throughout the previous season that in January the soil was practically air dry throughout its entire depth. Unfavorable moisture conditions will appear but slowly in these soils, but, when once developed, the impervious subsoil will make reclamation a difficult matter.

In the second group may be included all the soils of the Rositas series, the areas of the Holtville series having thin or shallow surface soils and the areas of the Meloland soils having deep surface soils. In the first two series the textures of the subsoils are light, i. e., light-textured silt loams or fine sandy loams to sands. In the Rositas series both the soil and subsoil absorb moisture rapidly and any excess of moisture moves into the deeper subsoil until arrested or retarded by meeting a substratum of heavier material. In the shallower members of the Holtville series any moisture reaching the subsoil is widely distributed throughout its mass and removed from the effects of surface evaporation. In the deeper surface soils of the Meloland series the surface soil takes up moisture readily, and when this has penetrated to the heavier subsoil it may be beyond the reach of the effects of surface evaporation. In this group the effect of continued irrigation upon conditions of subdrainage will depend upon the ability of the subsoils to remove any excessive amounts of subsurface waters, and the development of unfavorable conditions of subdrainage will probably not arise over any large and extensive areas.

In the third group may be included the very light textured soils of the Superstition series and associated types above the present

canal system. When placed under irrigation, the larger part of these soils will probably remain permanently free from the accumulations of excessive amounts of subsurface or drainage water. Unless artificial drainage be provided, however, there will tend to be eventually developed a water-logged area below and adjacent to and roughly parallel to the present high line canals, as the subsoil drainage waters from these pervious soils of the desert slopes will there meet the heavier subsoils of the Imperial and Meloland series, and be brought to the surface.

Certain areas with high water table, water-logged subsoils, or other evidence of retarded subdrainage have existed for several years, and according to reports, these areas are slowly increasing from year to year. It appears that this condition may be due, in part at least, to loss of water by seepage through the canal banks.

While deposition in the canals and ditches of large amounts of silt carried in suspension by the irrigation waters is having some effect in retarding the loss of water by seepage, it is probable that in certain localities only lining canals with concrete will effectually remedy the situation. Such means of prevention, with exercise of greater care and caution in the use of irrigation water and a more or less comprehensive system of drainage, will be the only effective means of improving the soils now so adversely affected, and in preventing the extension of the injury to unaffected areas.

## ALKALI.

During the process of decomposition and disintegration of rocks and rock fragments in the formation of soils, certain minerals and mineral compounds are dissolved by the percolating waters. In regions where the rainfall is sufficient to leach these materials from the soils and to maintain a movement of water through the soil and subsoil, these soluble materials do not accumulate in sufficient amounts to be detrimental to the growth of cultivated crops. In regions, however, where the rainfall is not sufficient to leach and carry the dissolved substance away from the soil, they tend to accumulate until the amount becomes sufficient either seriously to retard or altogether prevent the growth of crops.

Such excessive accumulations of soluble material are localized or brought about by the gradual evaporation of ground or surface waters from localities of arrested drainage or inclosed basins which have no drainage outlet. Such conditions exist quite commonly throughout the western part of the United States.

All that portion of the El Centro area below the line of the old beach probably was formerly a northern extension of the present Gulf of California, from which it was cut off by the development of a delta ridge by the Colorado River and changed to an inland lake.

The continued evaporation of waters which found their way into this depression has resulted in the deposition in the soils of the material carried in solution, which today forms the bulk of the alkali that is present in this area.

Under the normal desert conditions, there has probably been but little recent change in the distribution of the alkali salts in these soils. In the northeastern part of the survey there is an area in which there is apparently a slow movement of subsoil moisture from the higher desert regions to the east, which has resulted in the development of several hundred acres of alkali land in which the amount of salt is too high to allow the growth of cultivated crops, in many places the land being devoid of even the most alkali resistant vegetation.

The soluble mineral compounds formed or set free during the decomposition of rocks and soils include sulphate, chloride, carbonate, and bicarbonate salts of calcium, magnesium, and sodium. The principal salts found in alkali accumulations are: Sodium sulphate (Glauber's salts), sodium chloride (common 'salt'), sodium bicarbonate (baking soda), and magnesium sulphate (Epsom salts). Calcium carbonate (lime) is usually present in variable amounts, and calcium sulphate (gypsum) or sodium carbonate (sal soda) is present in many localities. All these salts excepting the last usually form white crusts upon the surface of the soil when present in large amounts and are commonly spoken of as "white alkali." When the last-named salt occurs in the presence of organic matter and moisture its presence is usually indicated by a dark-brown or black stain or crust on the surface of the soil, and "black alkali" is said to be present. Other substances tend to produce this same discoloration, and the stain is not always a definite indication of the presence of black alkali.

Alkali salts undergo movement or translocation only when there is a movement of moisture in the soil, and the rate of such movement is dependent both upon the amount of moisture present and upon the texture and structure of the soil. Other things being equal, the more rapid the movement of water through the soil the more rapid is the movement of alkali salts from place to place. In light-textured soils water moves quite rapidly either laterally or vertically, depending largely upon the structure of the soil, and this in part explains the sudden appearance of alkali in such soils after some years of irrigation, while near-by heavier textured soils apparently show no accumulations. Alkali salts are brought to the surface by the capillary movement and evaporation of moisture from the soil, where they are accumulated or concentrated at or near the surface and frequently appear as "alkali crusts." Alkali salts will also move laterally if the occurrence of the percolating subsurface waters and

the structure of the soil are such as to favor a movement of moisture in that direction, and under such conditions alkali may develop in districts far removed from any apparent source of such material.

Alkali may or may not be apparent from the surface indications, but its presence in considerable amounts is usually indicated either by the nature of the vegetation, by a puffy or mulch-like appearance of the surface soil, or by the presence of salt crusts on the surface of the ground. Upon irrigated lands a stunted, yellow or spotted growth of crops and the presence of alkali-resistant weeds and grasses are practically unfailing signs that dangerous amounts of alkali are present in the soil. It occasionally happens in the arid regions that the presence of alkali is masked to a large extent, and only an extensive series of tests to a depth of several feet can determine the location and concentration of alkali deposits present.

The harmfulness of alkali is dependent not only upon the amount present in the soil but upon its location in the soil profile, its chemical composition, the texture of the soil, and the amount of moisture that may be present, and it is often a difficult matter to determine just which of these conditions are most potent in the various localities in which damage may have resulted.

Generally speaking, concentrations of alkali of over 1 per cent (by weight of dry soil) are not tolerated by any cultivated crop; 0.6 per cent is usually tolerated by some of the native and cultivated grasses, sugar beets, some of the sorghums, and barley; 0.4 per cent is ordinarily not too high a concentration to allow the growth of alfalfa, the cereals (except Indian corn), cotton, and many of the root crops; and 0.2 per cent is usually insufficient to affect the growth of any ordinary field crops. The percentages given above presuppose that the alkali salts are uniformly distributed throughout the soil profile. This is seldom the case, as the salts tend to concentrate at various horizons depending upon the moisture conditions and the texture of the soil and subsoil material. The amounts of alkali that plants can withstand are very much lower than the above figures when the alkali is concentrated upon or near the surface.

The white alkali salts vary in degree of harmfulness, according to their composition. The chloride salts are generally considered the most harmful, the sulphates are somewhat less so, and the bicarbonates seem to have very little effect. The latter salts, however, are undesirable, since if present in considerable amounts they may undergo a chemical change and form the very dangerous black alkali. This is very serious for practically all cultivated crops when there is more than 0.05 per cent of it in the soil.

Other things being equal, the degree of alkali injury is largely determined by the amount of moisture in the soil. With a given percentage of alkali present, the strength of the solution in the soil

varies with the moisture content, and a crop thriving in a very moist soil may be entirely killed by the removal of a large part of the moisture, through the concentration of the solution of salts.

During this survey, in the determination of the amount of alkali and its location in the soil, frequent borings were made with a soil auger to a depth of 6 feet. The samples thus obtained were usually divided into foot sections, and the amount of alkali, expressed in terms of percentage of total salts in the air-dry soil, was determined in each section by measuring the electrical resistance of the soil with an instrument especially devised for this purpose. The total of the amounts of alkali in the several sections, divided by the number of the sections, is taken as the average amount of alkali in the soil to the depth of the boring.

When alkali is present in the soil to a harmful degree, the only permanent and entirely satisfactory remedy is to remove it by drainage and leaching. The effect of this operation, if thorough, is to wash it down through and out of the soil, thus permanently removing it from the reach of the plant roots. Where alkali is present in the soil in moderate amounts, and artificial drainage is not feasible, the best use may be made of the land by selecting such crops as are most tolerant to small amounts of alkali, and practicing such methods of tillage as will tend to reduce the evaporation of moisture and concentration of the salts in the surface soil. No reliance should be placed in the rather common belief that certain crops will remove alkali from the soil in sufficient quantities to improve it so that less resistant crops can safely be grown. Temporary improvement noted under such conditions will usually be found to be due to changed or improved methods of cultivation and irrigation, which have for the time being brought about desirable physical changes in the soil, or have driven the alkali into the deeper soil. The alkali content has not been materially reduced, and a return to the former crops and methods of cultivation will result in a return of the alkali to the surface.

The results of several hundred tests show that alkali is quite generally present in all of the soils of the area, excepting those which have been formed mainly by the action of the wind, and certain other light-textured soils upon the floor of the desert above the present irrigation canals. Aside from the area of soil in the northeastern portion of the area, which is not directly comparable with the rest of the area, the larger areas of alkali land are found in the central parts of the area and extending westward from El Centro and Imperial to a short distance beyond New River.

In mapping the alkali of the area the lands have been classed in four grades, with reference to alkali content and visible conditions,

the limits of each grade being determined partly by the total content of salts within the 6-foot section, and partly by the appearance and character of the crop.

The lands in the first grade may be considered as alkali free, since they contain less than 0.2 per cent of salts distributed in such a manner as to have caused no apparent effect on plant growth. This grade is rather inextensive and is confined mainly to the area of wind-blown soils along the margins of the desert and to a number of small bodies south and east of El Centro and south of Holtville. This grade includes some of the most desirable tracts of land in the El Centro area, and if properly handled no damage from alkali need be feared.

The lands of the second grade constituting slightly affected areas contains between 0.2 and 0.6 per cent of salts so distributed as to have no visible effect on crops. While these lands carry somewhat more alkali than the lands of the first grade, they have to the present time produced practically as good crops. With the higher content of alkali, however, greater care is necessary in handling them, as improper management may cause the salts to concentrate near the surface and thus to injure crops. This grade is extensive, occupying 31 per cent of the El Centro area. It includes much of the country adjacent to El Centro and Holtville and considerable areas between El Centro and Calexico.

The lands of the third grade, constituting moderately affected areas, include lands having less than 2 per cent of salts, distributed in such a manner as to have a visible effect on crops, but not to prohibit agriculture. Where the larger quantities of salts are present, they are invariably concentrated in the lower part of the soil section or beyond the reach of the roots of ordinary crops. On the other hand, where only a small percentage of salts occur, these are concentrated at or near the surface, where their influence on plant growth is felt. Crops on lands throughout this grade are spotted and the yields are lower than those obtained from the lands of the preceding grades. This grade of land is extensive in the El Centro area. It includes for the most part soils of heavy texture and especially types with heavy subsoils. The largest areas lie in the northern part of the area, near El Centro and east and west of Imperial. Inasmuch as alkali is already affecting crops on these areas, the lands of this grade demand careful handling in order to prevent the further concentration of salts near the surface.

The fourth grade of lands comprise the strongly affected areas. The total salt content varies greatly, some of the areas in this class containing only a small percentage of salts which have accumulated on the surface and prevented plant growth, while in other areas the

alkali may be distributed in high concentrations throughout the soil profile. As a rule, the lands of this grade are easily distinguished by the presence of a white crust upon the surface, by brown discolorations on the surface which remain moist, by the absence of vegetation, or by a very poor crop growth. In a few instances, as west of Imperial, the surface shows no indication of alkali, even though the total salt content in the 6-foot section is more than 3 per cent. Throughout this grade the lands are so strongly affected that profitable yields of the ordinary crops can not be produced. Aside from the rather extensive body west of Imperial, strongly affected areas occur along New River cut, throughout the heavy clays northwest of Seeley, and under the East Side High Line Canal.

Within the area of alkali land in the northeastern portion of the survey, and over much of the territory between Imperial and New River, the soils have but little apparent value until some means shall be taken to remove the alkali. Over the rest of the area included in the survey, where there is any alkali in the soil, the future productivity of such lands is quite closely related with the movement of the irrigation and subsurface waters. As long as a large part of the excess water applied to the fields can continue to move downward through the soil and out to drainage channels, the amount of alkali within the reach of the plant roots probably will not materially increase. When, however, natural drainage can not remove the excess of water, as is already the case in the various seepage areas mentioned above, the alkali will constantly increase until the land becomes practically worthless.

The facility with which lands may be reclaimed from alkali depends upon the texture and structure of the soil, and the location of any particular body in the area. Lands immediately adjacent to either the channels of New or Alamo Rivers, or the tributary washes, have available outlets to which drainage water may be carried. As the distance from these natural drainage outlets increases, artificial drainage outlets must be constructed. As these drainage canals must be deep and often miles in length, it is obviously impossible for the individual land owner to construct such a system, and the work can only be carried out through the concerted action of groups of individuals. Drainage operations may be financed and carried out by irrigation districts or drainage districts may be organized, under certain State laws, whereby the land owners in any locality may organize, tax their lands or sell bonds to procure funds for the carrying out of drainage works, and levy taxes for the maintenance of such a system. In this way it is possible for large areas to be provided with a thorough means of draining the subsoil, and thus effect the removal of any excessive amounts of irrigation water and any alkali that may be present.

## SUMMARY.

The El Centro area covers 540 square miles, or 322,560 acres. It is located in the extreme southern part of the Colorado Desert, in southeastern California, and is largely below sea level. The southern boundary of the area is the International Boundary between the United States and the Mexican State of Lower California. The area includes a part of the sloping and slightly rolling area of the desert, above an old beach line, but consists mainly of a more level uniform surface area below the beach line. The latter marks the shore line of the last body of water that occupied this depression and lies but slightly above the sea level contour.

The higher desert sections are drained by a number of characteristic shallow drainage ways that carry water only at long intervals. The discharge of none of these streams reaches the lower part of the depression, but is absorbed by the sandy desert soils above the beach line. New and Alamo Rivers occupy two deep gorges in the central part of the area, and afford a means of disposing of the waste irrigation waters. Prior to the recent flood from the Colorado River, these gorges were but little more than shallow arroyos, but they are now from 50 to 100 feet or more in depth, with an average width of about 1,000 feet. They discharge into the lowest part of the depression now occupied by the Salton Sea.

El Centro and Calexico are the two principal towns of the area. The former, which is the county seat of Imperial County, is located near the center of the area. The latter is located on the Mexican Boundary, about 14 miles southeast of El Centro. Other towns in the area are Imperial, Holtville, Heber, Seeley, and Dixieland.

Railway transportation is afforded mainly by a branch of the Southern Pacific Railroad which extends through the central part of the area. This branch connects with the Los Angeles and New Orleans main line of that system at Niland, about 35 miles north of El Centro.

The climate is arid, the annual rainfall at Calexico for a number of years being about 3 inches. The precipitation occurs during the winter months, and usually comes in a few storms of moderate to heavy precipitation. Slight frosts occur during the winter months, but many of the vegetable and small-fruit crops continue to grow throughout the year, and cotton often volunteers from one season to another. The summer temperatures are high, the thermometer usually reaching 100 degrees or more during every month of the year from April to October. Temperatures of 116° F. and 117° F. have been recorded at Calexico. High wind movement is not uncommon during the winter and spring months.

Prior to 1900 there were no permanent settlers within this area, and there was no land under cultivation. Water was first available for some of the land north of the Mexican boundary in 1902 and in 1909 there were about 190,000 acres of land under cultivation, and a total of 1,007 miles of main and lateral canals. The leading crops of the El Centro area are alfalfa, cotton, milo maize, and barley. Specialized crops, such as muskmelons, lettuce, asparagus, and tomatoes, occupy but a small acreage; but, as they are intensely cultivated and are the first of the season to reach the larger market centers, they are an important feature of the agriculture. Dairying is one of the important industries, and the winter feeding of cattle and sheep for market is growing in importance each year.

A large acreage of the farmed land within the area carries two crops each year. The truck crops may be succeeded by either grain or milo, and milo or grain are either reseeded or replaced by other early maturing crops.

Below the beach line practically all of the material of the soils is derived from the masses of sediments transported and deposited by the Colorado River during the time it flowed into this depression. The heavier types of these soils are prevailingly purplish or chocolate brown to brown in color, very compact, and sharply stratified. The lighter textured soils are of a similar color or slightly lighter brown, but since their deposition have been subjected to redistribution by the action of the winds and have a rolling, hummocky, or duny surface. Above the old beach line the soils are prevailingly light grayish brown to light gray or reddish and of sandy and gravelly textures to indefinite depths. The surface is often quite uniform in topography, but is also frequently eroded or rolling and broken by the occurrence of areas of Dunesand. Seven series of soils, including 21 types, have been recognized in the survey of this area, as well as 3 classes or types of miscellaneous materials.

Irrigation is absolutely necessary for the growth of cultivated crops. The water is obtained through the diversion of a part of the flow of the Colorado River at a point a short distance below Yuma, Ariz. Water is sold to the farmers at 50 cents per acre-foot for each 24 hours that it is used. To this cost of irrigation is added assessments that are levied for the maintenance and operation of the canal systems. About 75 per cent of the annual water delivery is made from April to September, inclusive.

Alkali is quite generally present in the soils below the old beach line, excepting where they have been formed largely by the action of the winds. Above the beach line the larger part of the soils are entirley free from alkali. In certain rather well defined areas the amount of alkali in the soil is so large that the attempts at crop

production have seldom been profitable, and parts of such areas are not now under cultivation. Aside from these bodies the average amount of alkali to the depth of 6 feet ranges from less than 0.2 per cent to 1 per cent of the air-dry soil, but in large parts of the survey the salts are concentrated in the subsoil and do not prevent successful growing of crops. Except where the normal distribution of the salts has been affected through seepage waters there has been no recent concentration of the alkali and there is little danger of further accumulations so long as the waste and seepage waters do not accumulate in excessive amounts. When such conditions arise a very complete system of artificial drainage will be imperative.

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